TECHNOLOGY QUARTERLY.

EDITED BY JAMES P. MUNROE.

VOL. III. FEBRUARY, 1890. NO. 1.

THE STUDY OF STATISTICS IN COLLEGES AND TECHNICAL SCHOOLS.

BY FRANCIS A. WALKER, PRESIDENT.

DURING the past twenty or even ten years there has been an astonishingly rapid development of historical and economic studies in our higher institutions of learning. At the recent meeting of the American Historical Association in Washington, President Adams of Cornell presented an account of the work at present done in history in our leading colleges. To one who graduated thirty years ago, this account reads strangely enough. In place of, at the most, a single brief series of lectures on the so-called philosophy of history, we now find course after course of advanced historical study, with the free use of the library and with the most improved methods of the German Seminar, offered to students as a leading feature of their undergraduate work. Several of our American colleges have developed these courses in such variety, to such an extent, and with such a wealth of material, that they might not unfairly be called schools of history; and every year sees this carried further and further, with continually better and better results.

In the kindred department of economics, the progress made in recent times has been second only to that which we have noted regarding history. Indeed, the progress in the case of economics has been smaller only in respect to the number of colleges which have undertaken extended courses. In the institutions where both the new departments of study and research have been given scope, the extent to which political economy has shared in the growth of the past few years can scarcely be said to be inferior to that obtained by history. Neither in the

ability and reputation of the instructing staff, nor in the number and variety of courses offered, nor in the attendance and enthusiasm of the classes formed, does political economy yield to history at Harvard, or Yale, or Columbia, or Cornell. Together these two closely related departments make up a very large and constantly increasing part of the modern university.

Unfortunately, while this rapid development of historical and economic work has been going on, a branch of study which has the highest virtue at once to train the hand of the historical or the economic scholar and to furnish him with professional tools of the first importance has been almost wholly neglected. I refer to statistics, whose very methods are hardly known to the great majority of our economists and historians; and which is still to have its first chair founded in an American college. There are, indeed, a few schools where a little elementary instruction has, of recent years, been given in the use of figures as a means of testing sociological conclusions; but in no one of them has a full, proper course of statistics been established. It cannot be long, however, before the growing interest in economics and history will compel the recognition of statistics as a distinct and an important part of the curriculum of every progressive institution. The main difficulty will be to find the men who have had the training, at once severe and liberal, which will qualify them to inspire and direct these studies.

The three uses of statistical study, aside from its value as a means of discipline, are, in their order from lowest to highest, as follows: —

First, to enable the student to detect the fallacies in conclusions drawn by others from quantitative statements concerning human affairs, actions, interests, in which adventitious elements lie concealed, or from which something essential, or at least relevant, has, by inadvertence or dishonest design, been excluded.

Secondly, to enable the writer or the speaker upon politics, economics, history, or sociology safely and effectively to illustrate and emphasize his conclusions, drawn from a study, itself perhaps mainly or wholly non-statistical, of the subject to which he devotes himself.

Thirdly, statistics may, under proper direction and with due safeguards, be used for the discovery of social laws.

The first of these objects could perhaps only be fully attained through those long and weary stages of training which would be required to qualify one for the highest exercise of the statistical faculty, as last stated; but a very large part, at least, of the result desired, can be reached by a little very elementary instruction. To take an illustration from another department of study, we may suppose that an adequate

course in logic, sufficient to make a man, otherwise well trained, a sound and accomplished reasoner, might be compassed in a certain number of exercises per week, continued through two academic years. Yet, if time be not afforded for such a course, a great deal might be done to enable the student to detect false conclusions on the part of others, and to save him from the grosser errors of reasoning in his own writing or speaking, by means of a dozen hours devoted to fallacies. In much the same way, if a full course in statistics cannot be given, a few exercises upon the abuses of statistics may at least serve to keep one for life from a certain class of blunders from which men of the greatest acuteness and learning might not otherwise be exempt.

Let us take an illustration of the sort of errors against which the merest elementary study of statistics might prove a sufficient protection. A meritorious writer adduces as a proof of the great fall of prices which took place in New England between 1630 and 1640, that a cow which, at the former date, was worth £25 to £30, would, at the latter date, have brought but £5 to £6. Now the bare facts here are not in dispute; nor is it to be questioned that a fall, a great fall, in prices did take place in New England during the period referred to. Yet the statement quoted contains a gigantic blunder, — a blunder which a student of statistics would probably be incapable of making. In 1630, the value of a cow in New England represented the immense cost and risk of bringing an animal, by a slow-sailing vessel, thousands of miles, through comparatively strange seas, into a foreign climate. Ten years later, the value of a cow represented only the cost and risk of rearing her upon the soil. The cow of 1630 might still be living, surrounded by ten, twenty, or fifty of her descendants, born in New England.

Errors of this type are countless. They occur in the writings, they are heard in the speeches, of men learned and otherwise acute, but who have never been trained to detect the fallacies that lurk so cunningly under all groups of figures. Volumes might be filled with instances of statistical blunders of a class which a very elementary course would forever render impossible to any careful writer or speaker. Such a course would embrace a host of illustrations, affording examples of the kinds of error which especially beset the use of figures for sociological purposes, and would direct the attention of the student to the best means of exercising care and pains in escaping them.

It is easy to say that, if statistics be in truth such "kittle cattle," if danger lurk thus under every group of figures relating to social and economic matters, it would be better to eschew statistics entirely. But mankind will not consent to give up an agent of such power, because of

the abuses to which it is subject. If all men at once honest and candid were to forbear to employ statistics in such discussions, lest peradventure they should lead some astray, we may be sure that all the dishonest and uncandid would resort to their tables and diagrams with redoubled zeal. There are few instincts more strong than that which urges men to give a quantitative expression to the results of human experience. Men will do it, or have it done for them by others. No warning as to the possible errors of such evidence can prevent this appeal, or diminish the eagerness with which it will be made. What we must needs do, if we will promote the truth, is to instruct and exercise the citizen, as far as we may, in the scrutinizing, sifting, and testing of alleged statistical proofs.

What has just now been said brings me to the second of the objects enumerated as to be sought through the study of statistics: namely, to qualify and prepare the future writer or speaker upon political and economic and social questions safely and effectively to illustrate his conclusions, derived perhaps through processes mainly or wholly non-statistical. I have said that the instinct which leads men to seek quantitative statements for the results of human experience is one of the strongest in our nature; and that people will have this done, whether it is to be done rightly or wrongly. He then, who, in addition to the merits of sound and just thinking on social subjects, possesses the power of aptly using statistics, acquires thereby a great advantage, whether in exposition or in controversy, over almost any one, however gifted or brilliant in argument or in the graces of speech, who has not this peculiar faculty. All who have widely observed audiences gathered for the purposes of political discussion must have seen the almost ludicrous liking which they have for statistical statements. The crudest thinking is oftentimes carried through by an array of worthless statistics, which would not bear a moment of cool, critical investigation. Quantitative statements that are scarcely even relevant to the subject are, for popular purposes, better than none. What power, then, can a real master of statistics wield over his hearers! Attend a meeting where Mr. David Wells is speaking, and see how he holds the crowded audience in close attention for two hours, with no help from rhetoric, elocution, or gesticulation, merely by the strong, vivid, effective way in which he marshals figures. There are few orators who can so completely command the thoughts of their hearers, for the same length of time, by all the graces of speech, or even by stately and beautiful thoughts, as this publicist, whose style of speaking is not merely unfinished, but positively bad. Mr. Cobden owed very much of his extraordinary power to the

same cause. Mr. Gladstone is an even more remarkable example of the virtue of this art. Unthinking people say that he must be a wonderful orator, because, in spite of the serried masses of figures which belong to a budget speech, he has more than once held the House of Commons strictly silent and attentive for the space of three or four hours. The fact is, that that remarkable success was not obtained in spite of statistics, but by reason of them. There is no spectacle on which men, whether more or less educated, look with more breathless interest than the marshalling of a vast array of figures, which move and take their allotted place, in natural succession and in due order, at the bidding of a real master of that art.

Since so much popular interest attaches to the use of statistics in addressing any large audience, whether from the platform or from the author's or editor's desk, it is clearly worth while for every person who is under training to become a writer or a public speaker to undertake all the instruction and practice which may be necessary to enable him to put together the facts and figures which relate to any chosen subject at least clearly and correctly. We cannot all be Cobdens, Gladstones, or Wellses; but every educated man can learn to construct tables and diagrams which will bear the test of a fair scrutiny and liberal criticism. To do aught in the way of statistics at which fools will not peck, is of course beyond any man's power.

Those who have never tried their hand at statistical work will fail to appreciate the difficulties to be encountered at the start, and the frequently recurring need of going back and beginning all over again. To go to a series of extended tables with multitudinous subdivisions, in which a given total is distributed among many classes, and to take therefrom just what you want, no more, no less, and no other, — to make sure that your parts when put together will form a whole, and that no direction conveyed by the heading of a single column has been neglected, — is a task for which men must be trained, and in which they must be practised, going from simple and easy examples to complex and difficult ones, by patient steps. The great majority of editors and writers for the press, the great majority of legislators and public speakers, either fail on such work, or, as is most likely, judiciously avoid the attempt, even though statistical matter altogether relevant to the subject, and which might be made most interesting to their readers or hearers, lies on every side of them. In my long experience in office at Washington, nothing struck me more forcibly than the helplessness of Congressmen — even, with few exceptions, the acutest and best trained — to get up the figures for their own speeches. No matter

how clear their conception of the positions they wished to present, few of them could readily and confidently resort to the government publications at hand for the statistical materials with which to illustrate and enforce their views; and the gratitude with which they would accept and acknowledge some trifling assistance from a well trained clerk was almost ludicrous. I do not intend any disparagement by this statement. Statistics have a language of their own, and he who would use them must first learn that language; and this is as yet taught scarcely anywhere.

A striking example of the liability to mistakes which constantly besets the compilation of statistical tables was afforded in a book published, some years ago, under the title, "The Statistics of the United States." The plan of the work was a good one; such a book was needed; but the author evidently had not had the training requisite safely to carry out his scheme without falling into the gravest errors. For instance, the work undertook to present the expenditures of the United States for each year since the formation of the government. The figures used were taken directly from the finance reports of the Treasury Department, and were hence of the highest official authority. Unfortunately, however, the compiler went for this purpose to the column of "Gross Expenditures," and transferred the figures he found there into his table. The result was that for some years he was out of the way by several hundreds of millions of dollars, since during these years the Treasury issued large loans to pay off other loans contracted during the war at high rates of interest. Thus, for 1868 this writer gave the expenditures of the government as $1,093,079,655, — a very expensive government indeed for a time of profound peace! The facts were as follows. The "net ordinary expenditures" of the government that year were $202,947,734; there was paid from the Treasury, in bond premiums, $10,813,349; and, as interest on the national debt, $143,781,592; making the total expenditures of the government on these accounts, $357,542,675. In addition, the Treasury redeemed bonds to the amount of $735,536,980; and this, mainly, out of the proceeds of fresh loans, at lower rates of interest. All this vast sum, more than twice the actual expenditures of the government, even after including bond premiums and the current interest on the public debt, was embraced in the financial statement of the last year of Mr. Johnson's administration. This mistake was committed in connection with each successive administration, from Washington's down.

It is needless to say, that blunders of such a magnitude completely destroyed the prestige of the book; and that, although it was intended

to be issued from time to time, with the facts and figures brought down to date, it was never heard of again.

Another example of statistics rendered actually delusive by the neglect of elementary considerations is found in a recent work on State and Municipal Taxation, a book which, in many of its views and suggestions, makes a valuable contribution to economic literature, but is, statistically, very faulty. Thus, in a "comparative table," showing the "principal receipts, total receipts, and total expenditures" of certain leading cities, New York is put down for $73,309,884 of total receipts, in 1886, and for $71,750,743 of total expenditures. Now the fact is, that nearly twenty millions alike of the receipts and of the expenditures represent nothing but temporary loans, contracted and paid during the year. City taxes come in mainly during a brief period. In order to prevent the necessity of keeping a vast sum of money in the treasury for months together, the government properly borrows in the "dry season," and liquidates its obligations when the taxes set in like a flood. Yet this fact was, in the work referred to, allowed to swell the expenditures of the city more than one third. Had the city treasurer found it expedient to borrow ten millions more for one, two, or three months, this would have carried the "expenditures" of New York up to eighty-one millions!

Instruction directly intended to qualify a student to use statistics, and to compile tables with ease, confidence, and accuracy, is now given at Harvard University, Columbia College, the Institute of Technology, and probably elsewhere. The pupil is taught to look up the data relating to a given subject, as these may be found scattered through long series of official reports; to bring the various statements together; to examine them as to their proper comparability; to test their accuracy by all means which may be available; and to put them together into tables. The student is further taught to work out the percentages involved, and to set one class of facts into relation with others; as, for example, to compute the ratio of valuation, or of expenditure, or of mortality, to each million or each thousand of the population concerned; and, finally, to make diagrams or charts, which shall exhibit graphically the several elements, taken in their due proportions, as ascertained by the investigation. In none of the higher institutions, however, is this branch of study carried as far as it ought to be; nor are all the methods of instruction in this department yet worked out to their greatest efficiency. Still, the good work has been well begun; and the constantly growing appreciation of the ability to compile and to use statistics for the purposes of political, economic, and social discussion cannot fail to cause a rapid

development of this feature of the college course. The American Statistical Association, under the able secretaryship of Prof. Davis R. Dewey, is doing much to promote this study; and it is the desire of its officers that its Journal may become to a considerable extent at once the organ of communication, of suggestion, and of friendly criticism among the working statisticians of the country, and the repository of the best essays in this line from our leading colleges and universities: affording, in the latter way, a great impulse to the study of statistics "where it will do most good," namely, in connection with the academic pursuit of history and economics.

The scope of this paper does not include a discussion of the subjects and the order of studies designed to give the investigator the power to discover statistically the laws which govern the action of social and economic forces. Such a course would necessarily be long and severe. It should, for the best results, embrace the highest mathematics of our American colleges, and should be largely directed to the development of the biological sense. The number of those who, otherwise than as a means of mental training, would have occasion to undertake such a course, would necessarily be small. There is reason to wish that all citizens, from the highest to the lowest, might undergo so much of training in statistics as should enable them to detect the errors lurking in quantitative statements regarding social and economic matters which may, by tongue or by pen, be addressed to them as voters or as critics of public policies. Comparatively few of these, however, will ever have occasion to prepare such statements for themselves, and would thus have use for the special faculty which is required for the compilation of statistical tables and diagrams. Far smaller still will be the number of those whose natural endowments and whose chosen pursuits would justify the long and laborious training, the patient practice, and the acquisition of the large and various learning, which alone can qualify the student of history, of sociology, or of political economy confidently and surely to educe from thousands of pages closely packed with figures some hitherto unsuspected law of human life or conduct.

EXPERIMENTS ON THE PREPARATION OF BOILED LINSEED OIL.

BY FRANK H. THORP, S. B.

THE composition and properties of the drying oils have been but little studied. About twenty-five years ago, Mulder[1] took up this subject and published his observations. Within the last few years other chemists have investigated the subject, but the particular changes which take place in the so called "boiling" of linseed oil have received little attention.

The drying of this oil is due to its oxidation, and the oxidation is greatly hastened by the "boiling." The dryer, or substance added to the raw oil, partially oxidizes the oil during the boiling, and when a thin layer of the boiled oil is exposed to the air it rapidly hardens owing to the further oxidation of the oil. The dryer dissolved in the oil acts, perhaps, as a carrier of oxygen from the air to the oil.

The dryers most commonly used are litharge, pyrolusite, borate of manganese, and zinc white. Recently the oxalate of manganese has been proposed for this purpose.[2]

According to Mulder, some of the linoleic acid is converted to linoleic anhydride during the boiling. This anhydride is a tough, elastic body. At the same time, some of the metal of the dryer forms a salt with the remainder of the acid, and this salt gives hardness to the varnish.

Hazura and Bauer[3] find that the rate of oxidation, and consequent hardening of the oil, depends on the ratio of linoleic and linolenic acids present.

When linseed oil is oxidized, it undergoes very marked changes in its physical properties; the color becomes darker, the oil becomes more viscid, and there is an increase in weight, sometimes equalling eight per cent. Some carbon and hydrogen are also driven off. These changes occur also during the process of "boiling." According to

[1] Die Chemie der austrocknenden Oele, Berlin, 1867.
[2] Casteloz, Bull. de la Soc. Chimique, Vol. L. pp. 597, 645.
[3] Monatsh., Vol. IX. p. 459.

Cloetz[1] the carbon and hydrogen eliminated do not all pass off as carbonic acid and water, but partly as an irritating vapor resembling acrolein. He has shown that the glyceryl is destroyed.

A good varnish must be thin enough to apply with the brush, must dry without cracking and with rapidity, and give a clear, colorless film, which should be somewhat flexible. Oil varnishes give tougher films than volatile varnishes.

Preparation of Boiled Oils.

The oil used was a very light yellow cold-pressed, raw, Calcutta linseed oil. The same quantity of oil, 50 c.c., was used in each experiment unless otherwise noted. The weight of 50 c.c. of this oil was found to be 45.7 grams. The quantity of dryer used in each case was noted.

The general process of boiling in each case was as follows.

The measured oil was heated in glass beakers of about 150 c.c. capacity, which were set in a pan of fine sand as closely as they would stand without touching. The sand bath was heated by gas burners beneath. Thus from four to six beakers were heated at one time. By the use of a sand bath, the temperature of the oil could be regulated better than by direct heating, and the danger of the taking fire of the oil was reduced. By raising the sand around the beakers to about one half the depth of the oil, the whole mass could be very evenly heated. The oil was frequently stirred during the heating. In the course of the experiments it was found that the size of the beaker and the quantity of oil used had a marked influence on the temperature. With a beaker of 250 c.c. capacity and containing 100 c.c. of oil, the temperature was found to be about 30° higher than in a beaker of 150 c.c. capacity containing 50 c.c. of oil, under similar conditions. The temperature in the larger beaker was also much more even.

As the presence of small quantities of water in the dryers caused violent ebullition and frothing when they were added to the hot oil, they were carefully dried before being stirred into the hot oil. In those cases where the dryer was added to the cold oil and slowly heated with the oil, it was seldom dried, as all water escaped before the oil was hot enough to froth or spatter. But salts with "water of crystallization" always caused some disturbance, since this water does not escape until the temperature is quite high. With clear raw oil there is no ebullition until a very high temperature is reached. At 220° small bubbles

[1] Bull. de la Soc. Chimique, Vol. III. p. 41.

begin to show around the edge of the oil surface, and white irritating vapors of very disagreeable odor begin to come off. But active boiling of the oil does not take place under 360°, which was as hot as these oils were in any case heated. In general, the best results were obtained with temperatures between 230° and 275°.

Lead Salts.

Litharge. — Six experiments were made with quantities of litharge, varying from one half of one per cent to two per cent of the weight of the oil, and temperatures varying from 220° to 300°. Two of these experiments yielded fairly good boiled oils. The first was made with one per cent of litharge and at a temperature of 250° for two and one quarter hours; the second, with about two per cent of litharge and a temperature of 220° for one and a half hours. The remaining four experiments did not give good boiled oils.

Lead Peroxide. — One experiment only was made, at a temperature of 220°, but the resulting oil was worthless on account of its exceedingly dark color.

Red Lead. — Two experiments, at temperatures from 220° to 285°, gave unfavorable results.

Lead Carbonate. — Three experiments, with about one per cent of carbonate in each, and temperatures from 225° to 250°, were made. One, in which the temperature was kept at 225° for two hours, gave a fairly good boiled oil; the others were worthless.

Lead Nitrate. — One experiment, with two and one half per cent of nitrate and a temperature of 250°, resulted in a worthless mass of tar.

Lead Sulphate. — One experiment, with about two and one half per cent of sulphate and a temperature raised to 300° for nearly two hours, produced a very thin turbid oil, of no value. The sulphate did not decompose, even at this high temperature.

Lead Chloride. — Three experiments were made with the chloride, the quantities used varying from one to two and one quarter per cent, and the temperature from 250° to 360°. The first, with two and one quarter per cent of chloride and a very high temperature for one and three quarters hours, yielded a very sticky and elastic gum-like mass. In the other two cases, with lower temperatures, there appeared to be but little action on the oil.

Lead Oxalate. — One experiment, with about two and one quarter per cent of oxalate and a temperature at one time over 300°, yielded a thin and turbid oil of no value. Apparently the salt did not decompose. The oil did not dry.

Lead Acetate. — One experiment, with three per cent of acetate and a temperature of 300°, gave a very dark-colored oil which dried very slowly.

Lead Borate. — Two experiments, with about two per cent of borate and temperatures of 220° and 300° respectively, were made. The first gave a dark brown oil, and the other a dark reddish-brown oil. Both oils were quite fluid.

Lead Tartrate. — One experiment, with about two and one half per cent of the salt and a temperature of 270°, was made. The tartrate did not decompose until a high temperature was reached, and the boiled oil was very dark-colored and viscid.

Mixtures. — Two experiments with mixtures of litharge and red lead were made. Two per cent of each oxide was used, and the temperatures kept below 250° in one case, and 230° in the other. The boiled oils were quite fluid, but very dark-colored.

Two experiments with mixtures of litharge and acetate were made, using two per cent of each and keeping the temperatures as in the above cases. The results were better with these, although the oils were quite deeply colored.

Zinc Salts.

Zinc Oxide. — Two experiments, with one and two per cent of oxide respectively, and the temperature at 250°, were made; both gave turbid oils which did not clarify satisfactorily. The colors were light brown. These oils dried very slowly.

Zinc Sulphate. — Two experiments were made with this salt, using nearly four per cent in one case and three per cent in the other. In the latter case the sulphate was added to the cold oil and heated with it. The temperature in this case was raised to 285°. The oil was poor. In the former case the temperature was kept below 230°. The oil was light red in color, and the sulphate appeared to have very little action.

Zinc Carbonate. — One experiment, with three per cent of the salt and a temperature of not over 230°, gave a poor result. It was, in fact, much like the oxide.

Zinc Acetate. — Two experiments, with two and four per cent of acetate and temperatures between 235° and 280°, gave red oils, which were clear and fluid, but slow-drying.

Zinc Chloride. — One experiment with this salt resulted very similarly to the first lead chloride experiment. A semi-solid mass was formed.

Zinc Borate. — Three experiments, with two per cent of the salt and a temperature not over 240°, gave fluid dark red oils, which dried slowly.

Zinc Oxalate. — One experiment showed that the oxalate did not act on the oil after prolonged heating at 260°; on raising the temperature to 300°, the oil was converted into a mass of tar.

Zinc Citrate. — One experiment, with three per cent of the salt and the temperature at 230°, gave a fairly good, clear oil, which dried rather more rapidly than the oils prepared with the other zinc salts.

Zinc Tartrate. — One experiment, with three per cent of the salt and a temperature of 300° was made, but the salt appeared to have very little action upon the oil.

Manganese Salts.

Manganese Binoxide. — One experiment, with one per cent of the oxide and a temperature not over 220°, gave a very dark-colored boiled oil.

Manganese Carbonate. — One experiment with this salt, at a temperature not over 250°, gave a reddish-brown boiled oil, much like the best oils obtained with litharge.

Manganese Acetate. — Three experiments, with quantities of the salt from one to two per cent and temperatures from 225° to 250°, gave red boiled oils of varying depth of color. All dried quickly, and were good boiled oils.

Manganese Borate. — Two experiments, with one and three per cent respectively of this salt and temperatures of 230° and 220°, gave the best oils obtained in the entire investigation. The boiled oils were clear, fluid, and light colored. They dried quickly, and gave good films.

Manganese Sulphate. — Three experiments, with from two to about three per cent of this salt and temperatures from 240° to 300°, gave varying results. At 300° the sulphate decomposed rapidly, and tarred the oil; at the low temperatures there was less action, and good clear oils were obtained.

Manganese Oxalate. — Five experiments, with from one to three per cent of the salt and temperatures from 230° to 315°, gave rather unsatisfactory results. At the lower temperatures the oxalate did not appear to decompose, and the oils were turbid from sediment, which did not settle on long standing. These oils were light in color, but dried rather slowly. At the high temperatures, there may have been some decomposition of the salt, but the oils obtained were also turbid, and, in one case, quite dark-colored.

Manganese Citrate. — One experiment, with three per cent of the salt and the temperature at 230°, gave a very dark-colored oil.

Manganese Tartrate. — Two experiments, with from two to three per

cent of tartrate and temperatures from 230° to 260°, were made. The first gave a very good oil; the other did not.

Manganese Formate. — Two experiments were made with this salt. In the first, two per cent of the salt was used, and the oil was converted into tar. In the second, one per cent of salt was used and the temperature kept below 200°, the time of heating being about one hour. The boiled oil obtained dried very fast, but was very dark brown in color. The result was not good.

DRYING TESTS.

Dryer.	Quantity of Dryer used.	Time of Boiling.	Time required for Drying.	Character of the Film.
	Grams.	Hours.	Hours.	
Litharge	1.0	2¼	6	Almost colorless.
"	0.2	2¼	10	" "
"	0.8	1½	10	
Lead peroxide	1.072	1½	Several days.	Deeply colored.
Lead chloride	1.247	2½	24	Somewhat colored.
Red lead	1.024	2½	24	Deeply colored.
Lead oxalate	1.323	2¼	Did not dry.	
" tartrate	1.6	2¼	24	Deeply colored.
" acetate	1.46	2¼	12	Somewhat colored.
" borate	1.105	1½	20	Slightly colored.
" carbonate	1.197	2	10	" "
Zinc oxide	0.5	2¼	45	Nearly colorless.
" sulphate	1.987	2½	45	" "
" sulphate	1.5	2½	45	Yellow in color.
" acetate	1.0	2¼	40	Colorless.
" borate	1.0	2	40	Nearly colorless.
" "	0.5	1½	46	" "
" "	0.5	1½	46	" "
" citrate	1.5	2½	36	" "
Manganese acetate	1.0	2¼	20	Nearly colorless.
" borate	1.625	2¼	20	Colorless and hard.
" sulphate	1 72	2	40	Colorless.
" oxalate	1.64	2	40	"
" acetate	0.5	2	20	Deeply colored.
" borate	0.5	1	20	Colorless.
" acetate	0.5	1¼	20	"
" oxalate	1.5	2½	36	"
" sulphate	1.5	2½	36	"
" oxalate	1.0	2¾	48	Yellow in color.
" citrate	1.5	1½	24	Dark colored.
" tartrate	1.0	2½	24	Colorless.
" formate	1.0	1	24	Somewhat colored.

Small plates of glass were used for these tests. These were coated with a film of the oil, and were then placed in a light room to dry. The temperature of this room varied somewhat, but was commonly about 70° F. during the day. Generally, from a dozen to twenty samples were tested at a time. The films were considered to be dry when they could be handled without leaving finger-marks upon them. The plates were examined at intervals of several hours, and only relative results as to the time of drying were expected. The chief points looked for were the color and hardness of the film. The results are given in brief in the foregoing table.

Examination of the Boiled Oils.

The analyses given below were made in the hope of throwing some light upon the relation between the quantity of dryer dissolved and the rate of hardening of the oil.

For the determination of the lead the following method was used. A weighed amount of oil was carbonized in a small evaporating dish, and then ignited over a Bunsen lamp until all the carbon was burned off. The residue was digested with hot dilute nitric acid, and filtered. The lead was then precipitated as sulphate, with the usual precautions, and weighed. The following results were obtained.

Boiled Oil.	Quantity of Dryer added.	Per cent of Metallic Lead in the Boiled Oil.		
		Calculated.[1]	Found.	
	Grams.		I.	II.
Lead carbonate	1.197	2.03	1.392	1.477
Lead acetate	1.466	2.23	1.396	1.338
Litharge	0.2	0.406	0.244	—
Lead borate	1.105	2.03	0.982	0.998

From the drying tests it will be seen that the first two oils in the above table dried in nearly the same time, and gave very similar results.

[1] The quantities in this column are the calculated per cents of metallic lead which the boiled oil would have contained if all the salt added to the raw oil had been dissolved in the boiled oil. But in no cases was the dryer entirely dissolved in the oil, a sediment of undecomposed salt of greater or less quantity always settling on the bottom of the bottles upon standing several days. Only the clear oil from the upper part of the bottle was used for these analyses.

But the third oil dried in half the time required for the fourth, although the latter contains more lead.

In the determinations of manganese in the oils, the following method was used. The oil was weighed and charred in an evaporator. It was then ignited over a Bunsen lamp until all the carbon was burned off. The residue was digested with dilute hydrochloric acid and heated nearly to boiling, filtered, and neutralized with ammonia. Some ammonium chloride was then added, and then an excess of sodium phosphate. The precipitate was filtered off, dissolved in hydrochloric acid, avoiding an excess of acid, and the solution heated to boiling. Ammonia was then slowly added to the boiling solution until a large excess was present. The precipitate was boiled, without filtering, for ten minutes, to convert the phosphate of manganese to a scaly form, and was kept hot for about one hour longer. It was then filtered off, washed with dilute ammonia, ignited to the pyrophosphate, and weighed. The following results were obtained.

Boiled Oil.	Quantity of Dryer added.	Per cent of Metallic Manganese in the Boiled Oils.		
		Calculated.[1]	Found.	
	Grams.		I.	II.
Manganese sulphate	1.72	1.37	.045	.038
Manganese borate	1.62	2.06	.208	.190
Manganese acetate	0.5	0.347	.248	.256
Manganese oxalate	1.5	1.034	—	.030
Manganese tartrate	1.5	0.670	.049	.043

From the drying tests it will be seen that the first and fourth oils above analyzed dried very slowly, while the last one, with about the same quantity of manganese, dried in about one half the time required for the first and fourth.

Conclusions.

Lead dryers always give the oil a deep color, which shows more or less in the film.

Zinc dryers do not appear to act on the oil to any great degree, as oils thus prepared dry slowly and do not give very hard films.

[1] See note to the preceding table.

Manganese dryers give the best results in all respects. Litharge gives the best results of the lead dryers, the oil being quick-drying and the film hard, and, if not overheated, the oil is but moderately colored. Of the zinc salts, the acetate seemed to give the best result, although the borate and citrate were nearly as good. The borate and acetate of manganese gave the best results obtained. The acetate requires careful use, for, if heated much above 230°, it gives a deep color to the oil, owing apparently to the formation of tar. The borate undoubtedly gives the best boiled oil for all purposes.

The oxalate is difficult to decompose, or at least has little or no action on the oil until a very high temperature is reached. In two experiments the quantities of borate and oxalate used and the temperatures of each were nearly the same, but the borate gave a good oil, while the oxalate did not.

The chlorides, nitrates, and sulphates do not make good dryers. The first two have too violent an action on the oil, while the last are very difficult to decompose, requiring a high temperature.

There appears to be no advantage in the use of formates, citrates, or tartrates. The first two are apt to produce much tar, and the last are difficult to decompose.

No very definite conclusions can be drawn as to the relation between the quantity of dryer dissolved and the rate of drying of the oil. From the few analyses made there would appear to be some relation here; but in two cases, lead borate and manganese tartrate, exceptions were found. The lead borate gave an oil drying much more slowly than was to be expected, while the manganese tartrate oil dried with comparative rapidity. The quantity of manganese dissolved appears to be much less than the quantity of lead taken from lead dryers. Two tenths of one per cent of manganese appears to give a good drying oil, while about one per cent of lead occurs in the best drying oils.

DATA AND PLOTS OF VARIOUS INCANDESCENT LAMPS, TOGETHER WITH AN IMPROVED METHOD OF TESTING.[1]

BY WM. L. PUFFER, INSTRUCTOR IN PHYSICS.

SINCE the appearance of the report of the Franklin Institute on incandescent lamps, in 1885, there have been no published measurements either of the efficiency or of the distribution of light of the best known lamps now in the market. But the market lamps of to-day are much better than those of 1885, so much so, in fact, that the Franklin Institute data, although very valuable as showing the state of the art in 1885, are of no especial value for use with the lamps now manufactured.

The following data and curves have been calculated and plotted from the observations made by Messrs. Walter G. Whitmore and Edwin R. Pearson, class of 1887, Massachusetts Institute of Technology, who took as the subject of their graduating thesis "A Study of the Efficiency of Incandescent Lamps." The method used is substantially like that of the Franklin Institute, but I have changed and improved the method of plotting so that the five plots tell the distribution of light, shape of filament, and its position in regard to photometer, etc. This method of testing lamps is in regular use in the laboratory, with very satisfactory results.

The standard of light used is a Methven screen which has been standardized by comparison with many standard candles at different times and by different observers, and also with a Harcourt standard burner. The mean of a large number of observations agrees so closely with the maker's value of two candles, that this is assumed to be right within the limits of error of the photometer, and no correction is used.

The photometer is a modified Bunsen, 100 inches long, graduated into inches and tenths by a dividing engine, and having also a scale of "ratios" which, when multiplied by the candle-power of the standard, give candle-powers directly. Both the standard burner and the lamp under test are thoroughly screened, so that little if any diffused light

[1] Reprinted from the *Electrical Engineer*, New York, January and February, 1890.

reaches the eye of the observer. A key near the observer's hand and a lamp overhead furnish light when needed for reading.

The lamp-holder is quite different from that used by the Franklin Institute, and will hold any of the lamps now in the market without danger of straining. The socket with lamp under test is screwed on the end of a brass rod, which is free to slide or rotate in a sleeve fixed in the centre of and perpendicular to a disk of brass. Set screws are provided for clamping the rod in the sleeve. The disk is arranged on the bottom of a U-shaped strap in such a position that it can be turned, while the rod always remains parallel to the sides of the U and in the same plane. The disk has notches every five degrees, and the strap carries a locking pawl, which also serves as an index.

The U-shaped strap is pivoted near the top in a frame, so as to have rotation about a horizontal axis; it also has a notched disk, and the frame a pawl and index. One arm of the U is longer than the other, and carries a movable counterweight.

This apparatus is set with the horizontal axis perpendicular to the line of the photometer and on a level with the centre of the greased disk; the vertical circle being adjusted to read 0° when the lamp stands vertical with the socket underneath, then the horizontal disk is placed at 0° and the rod carrying the lamp moved till the plane of the shanks is perpendicular to the line of the photometer and the horizontal axis cuts the filament midway of its length. This position of the lamp is called the "standard position," and the photometer reading for this position the "standard reading." By means of the horizontal circle any desired degree of longitude can be instantly turned towards the photometer, and, by the vertical circle, any degree of latitude. Flexible wires connected directly to the socket are used for current leads, and another set is used for measuring the potential at the lamp terminals. It is assumed that the socket and the lamp terminals will be of the same potential, except with very low resistance lamps, or with lamps requiring a large current.

Electrical measurements were made by a set of carefully calibrated Thomson's current and potential galvanometers, placed in a room free from magnetic disturbances, where the value of the earth's component had been determined. As the current taken by the potential galvanometer bears a very sensible ratio to that in the lamp, the instrument is always kept in circuit and a correction is made for the current passing through it. An adjustable resistance in the lamp circuit enabled the observer to keep the potential at the right amount. The potential galvanometer used was adjusted for Rayleigh volts, and as the difference

between this and Legal volts is nearly within the limits of accuracy of the instrument no correction for reduction to the latter was made. It was assumed that the voltage marked on the lamps was in Legal volts, and that if the lamp changed its resistance while under test the volts must remain constant, and the current and candle-power allowed to vary. If any lamps were marked in terms of the B. A. volts, then they were tested at too high a voltage.

When the lamp had been placed in the "standard position" and the potential adjusted, candle-power readings were taken at 65 different positions; the value used for each position being the mean of three or four settings of the disk, according to the method used by the observer.

The standard direction, to which all others are referred, is a line perpendicular to the plane of the shanks of the filament and lying in the equator of the lamp. By equator is understood the line cut upon the glass globe of the lamp, when upright, by a horizontal plane half-way up the filament. Zero point, or 0°, is the starting point for measuring the angular rotation of the lamp, and is at the intersection of the standard direction and the equator.

Horizontal distribution is measured by candle-power readings at each 30° around the equator, beginning and ending with 0°, or the "standard direction." Of these 13 c. p. readings, the first and last should, of course, check.

Mean horizontal candle-power is the mean of the first 12 of these readings, the check reading being omitted.

Vertical distribution is measured on each of four complete meridians, i. e. those of 0°, 45°, 90°, and 135°, on the equator. On each of these four circles candle-power readings are taken at every 30° (of latitude), beginning and ending with 0°, thus giving 13 readings, the first and last of which should check.

Standard reading is the mean of all readings in the direction of the zero point ("standard position"). It is an arbitrary position selected for convenience. By it and the "reduction factors" the candle-power (spherical or horizontal) may be determined under any given potential or current, at any subsequent time, by one reading. Great care should be taken in placing a lamp in this position, because in some lamps a very slight error would make a very considerable difference in the candle-power, and of course in the "factors." When a number of tests are to be made on any one type of lamp, it is preferable to select a point on the horizontal circle in that part of the curve where the rate of change of candle-power is very small, and so avoid error due to hasty or imperfect setting of the lamp for the standard reading.

Mean spherical candle-power is computed from 38 readings, selected from those described, with the aim of obtaining the average intensity of light in all directions. These readings are as follows: —

Mean of 4 north pole readings (longitude 0°, 45°, 90°, 135°) counts . .							1
Longitude	0°,	Latitude 60°,	120°,	240°,	300°,	giving	4
"	90°,	" 60°,	120°,	240°,	300°,	"	4
"	0°,	" 30°,	150°,	210°,	330°,	"	4
"	45°,	" 30°,	150°,	210°,	330°,	"	4
"	90°,	" 30°,	150°,	210°,	330°,	"	4
"	135°,	" 30°,	150°,	210°,	330°,	"	4
Equator, 12 readings (or mean horizontal × 12) counts							12
South pole reading assumed zero and counts							1
Total							38

The values for these positions are selected, added, and divided by 38.

Horizontal reduction factor is the mean horizontal candle-power divided by the standard reading.

Spherical reduction factor is the mean spherical candle-power divided by the standard reading.

The mean spherical candle-power divided by the mean horizontal candle-power gives a very useful factor, which is not so much affected as the two above by a slight error in setting the lamp in the exact standard position. Inspection of the curve for the 70-volt Weston lamp will show that a very slight error would materially change both the horizontal and the spherical reduction factors, but would not alter the ratio of the two. Obviously the product of the standard reading taken at any time and the reduction factors will give the horizontal or spherical candle-power without any other measurements.

The method of plotting the results of a test on a lamp is thought to be an improvement on the Franklin Institute method, and is designed to show at a glance,—

1. The distribution of light in five great circles. 2. The relative position of the lamp filament to the photometer at the zero of each circle. 3. The appearance of the filament as seen from the photometer disk at the zero of each circle. 4. The rated candle-power. 5. The mean spherical candle-power. 6. The mean horizontal candle-power. 7. A table of data.

For example, take the 70-volt Weston lamp. This lamp has a zigzag filament of rectangular section, twisted when mounted, which gives a very characteristic set of distribution curves.

On the horizontal plot we see the photometer bar represented by the black line on the left, and in the centre is the horizontal projection of the filament at the zero position, " with the plane of the shanks perpen-

dicular to the line of the photometer bar," and also a drawing of the filament as seen from the photometer disk at the zero of the circle. The curve shows that the light is greatest at about 150° and 330°, and weakest at about 60° and 240°; now, according to the Philadelphia method, we could not tell why this is so, but a glance at the projected filament (and also at the pictures of the filament seen at 0°, 45°, 90°, and 135°) shows that in one case the sides and in the other the edges of the corrugations correspond with the highest and lowest photometer readings. This plot also shows that the mean spherical candle-power is nearly equal to the mean horizontal, but that neither is up to the rating of 16 c. p. under any reasonable assumption that can be made as to the meaning of that term. The observed candle-powers are indicated by the figures written near the intersection of the curve and the radii, drawn 30° apart.

The next plot shows the distribution of light in a vertical plane passing through the zero of the horizontal circle. As before, the horizontal projection of the filament is seen in its position relative to the photometer bar at the zero of the circle, and a drawing of the filament as seen from the photometer at the zero position.

The next plot shows the distribution in a vertical plane passing through 45° on the horizontal circle. The projection of the filament shows that the divided plate and lamp was turned 45° right-handedly, thus bringing the 45° position on the horizontal plot towards the photometer. The diminished amount of light is due, as indicated by the sketch of the filament, to the presentation of the edges of the carbon to the photometer. The next two plots are taken in a similar way at 90° and 135° respectively on the horizontal circle.

The pictures of the filament were obtained by holding the lamp behind a plate of glass and before a bright lamp and tracing the shadow of the filament. The scale of plotting is, unless otherwise stated, 0.1 inch per candle, and the filaments are drawn "life size."

All of these lamps were bought, in the winter of 1886–87, of supply companies in Boston, out of stock, and presumably could not in any way be picked lamps.

The Edison lamps had the copper-plated shanks, and are now (1889) known as the "old lamp." The Weston 110-volt lamp is not now in the market, and I believe was on sale for only a short time after these were bought, an improved lamp taking its place. I do not know whether the 70-volt Weston lamp of the kind tested is in the market or not. The Thomson-Houston and Swan lamps appear similar to those now in the market, and are, as far as I know, the same.

RESULTS CALCULATED BY WM. L. PUFFER, FROM THE OBSERVATIONS OF MESSRS. WHITMORE AND PEARSON, CLASS OF '87.

Lamp. — 1887.	Mean standard reading.	Mean spherical c. p.	Spherical reduction factor.	Mean horizontal c. p.	Horizontal reduction factor.	Spherical ÷ horizontal.	Volts.	Amperes.	Watts.	Watts per spherical c. p.	Watts per hor. c. p.	Lamps per electrical horse-power.	Mean spher. cand. per electric'l horse-p.	Mean hor. can. per electric'l horse-p.
Weston 70-volt, 16 c. p.	16.63	14.25	0.857	15.13	0.909	0.942	69.96	1.021	71.43	5.01	4.72	10.4	149	158
Weston 110-volt, 16 c. p.	8 97	10.96	1.222	13 37	1.491	0.820	110.1	0.530	58.36	5.32	4.36	12 8	140	171
Thomson-Houston 52.6-volt, 20 c. p.	21.00	16.82	0.801	20.68	0.985	0 813	52.61	1.250	65.76	3.91	3.18	11.3	191	235
Thomson-Houston 75-volt, 16 c. p.	16.00	13.31	0.832	16.18	1.011	0.823	74.98	0.705	52.87	3.97	3.27	14.1	188	228
Thomson-Houston 110-volt, 16 c. p.	13.00	10.50	0.808	12.86	0.990	0.816	100.1	0.472	51.96	4.95	4.04	14.4	151	185
Edison 101-volt, 10 c. p.	10.50	8 25	0.786	10.38	0.987	0.795	100.9	0.512	51.65	6.26	4.98	14.4	119	150
Edison 101-volt, 16 c. p.	13.00	13.25	1.020	16.46	1.27	0.805	100.9	0.789	79.58	6.00	4.84	9.4	124	154
Edison 101-volt, 32 c. p.	26.53	28.59	1.078	34.21	1.290	0.836	100.9	1.295	130.7	4.57	3.82	5.7	163	195
Swan 36-volt, 8 c. p.	8.09	6.61	0.817	7.76	0 959	0.852	35.96	0.786	28.26	4.27	3.64	26.4	175	205
Swan 38-volt, 16 c. p.	13.10	10.57	0.807	12.25	0.937	0.863	38.05	1 300	49.65	4.70	4 05	15.0	179	203
Swan 46-volt, 8 c. p.	7 39	5.89	0.797	6.70	0.907	0 879	45.99	0.534	24.56	4.17	3.67	30.4	210	244
Swan 46-volt, 16 c. p.	15.54	14.38	0.925	16.73	1.077	0.859	45.99	1.113	51.18	3.56	3.06	14.6	141	177
Swan 92-volt, 10 c. p.	8.88	7.17	0.807	9.03	1.027	0.794	91.98	0.413	38.00	5.30	4.21	19.6	157	191
Swan 92-volt, 16 c. p.	15.30	11.49	0.751	14.00	0.915	0.821	91.98	0.594	54.64	4.76	3.90	13.7	185	217
Swan 92-volt, 32 c. p.	33.57	27.74	0.826	32.48	0.968	0.854	91.98	1.215	111.8	4.03	3.44	6.7	159	184

1887. LAMPS IN ORDER OF EFFICIENCIES EXPRESSED IN TERMS OF WATTS PER HORIZONTAL CANDLE-POWER.

	Lamp.	Voltage.	Rated candle-power.	Watts per candle-power.	Candles per electrical horse-power.
1	Swan	46	16	3.06	244
2	Thomson-Houston	52.6	20	3.18	235
3	" "	75	16	3.27	228
4	Swan	92	32	3.44	217
5	"	36	8	3.64	205
6	"	46	8	3.67	203
7	Edison	101	32	3.82	195
8	Swan	92	16	3.90	190
9	Thomson-Houston	110	16	4.04	185
10	Swan	38	16	4.05	184
11	"	92	10	4.21	177
12	Weston	110	16	4.36	171
13	"	70	16	4.72	158
14	Edison	101	16	4.84	154
15	"	101	10	4.98	150

1887. LAMPS IN ORDER OF EFFICIENCIES EXPRESSED IN TERMS OF WATTS PER SPHERICAL CANDLE-POWER.

	Lamp.	Voltage.	Rated candle-power.	Watts per spherical candle-power.	Candles per electrical horse-power.
1	Swan	46	16	3.56	209
2	Thomson-Houston	52.6	20	3.91	191
3	" "	75	16	3.97	188
4	Swan	92	32	4.03	185
5	"	46	8	4.17	179
6	"	36	8	4.27	175
7	Edison	101	32	4.57	163
8	Swan	38	16	4.70	159
9	"	92	16	4.76	157
10	Thomson-Houston	110	16	4.95	151
11	Weston	70	16	5.01	149
12	Swan	92	10	5.30	141
13	Weston	110	16	5.32	140
14	Edison	101	16	6.00	124
15	"	101	10	6.26	119

1887 LAMPS. TABLE SHOWING CANDLE-POWER ACTUALLY GIVEN OUT ON THE HORIZONTAL CIRCLE IN PERCENTAGE OF THE RATED CANDLE-POWER.

	Lamp.	Voltage.	Rated candle-power.	Per cent.
1	Edison	101	32	107
2	Swan	46	16	105
3	Edison	101	10	104
4	Thomson-Houston . . .	52.6	20	103
5	Edison	101	16	103
6	Swan	92	32	102
7	Thomson-Houston . . .	75	16	101
8	Swan	36	8	97
9	Weston	70	16	94.6
10	Swan	92	10	90.3
11	Swan	92	16	87.5
12	Weston	110	16	86.3
13	Swan	46	8	83.8
14	Thomson-Houston . . .	110	16	80.4
15	Swan	38	16	76.6

1887 LAMPS. TABLE SHOWING CANDLE-POWER ACTUALLY GIVEN OUT IN SPHERICAL CANDLE-POWER IN PERCENTAGE OF RATED CANDLE-POWER.

	Lamp.	Voltage.	Rated candle-power.	Per cent.
1	Swan	46	16	89.9
2	Edison	101	32	89.4
3	Weston	70	16	89.1
4	Swan	92	32	86.7
5	Thomson-Houston . . .	52.6	20	84.0
6	" " . . .	75	16	83.2
7	Edison	101	16	82.9
8	Swan	36	8	82.6
9	Edison	101	10	82.5
10	Swan	46	8	73.6
11	"	92	16	71.8
12	"	92	10	71.7
13	Weston	110	16	68.5
14	Swan	38	16	66.1
15	Thomson-Houston . . .	110	16	65.6

COMPARISON OF LAST FOUR TABLES, SHOWING POSITION OF LAMPS WHEN COMPARED ACCORDING TO THE METHODS.

Lamp.	Voltage.	Rated candle-power.	Watts per spherical c. p.	Watts per horizontal c. p.	Per cent spherical c. p.	Per cent horizontal c. p.
Swan	46	16	1	1	1	2
Thomson-Houston . . .	52.6	20	2	2	5	4
" " . . .	75	16	3	3	6	7
Swan	92	32	4	4	4	6
"	46	8	5	6	10	12
"	36	8	6	5	8	8
Edison	101	32	7	7	2	1
Swan	38	16	8	10	14	15
"	92	16	9	8	11	11
Thomson-Houston . . .	110	16	10	9	15	14
Weston	70	16	11	13	3	9
Swan	92	10	12	11	12	10
Weston	110	16	13	12	13	13
Edison	101	16	14	14	7	5
"	101	10	15	9	9	3

A study of these tables and plots will make it very evident that there is no commonly accepted value of a candle-power, or, if there is, that different makers vary widely in their attempt to produce it. The question, "What is meant by a 16 c. p. incandescent lamp?" has not, I believe, been settled by the courts, and until it is there will be endless dispute as to whether a given lamp is "up to candle-power or not."

For example, take the Edison 101-volt 16 c. p. lamp; if we rate it by the light given off "on the face of the loop," i. e. the standard reading, it is evidently 13.00 c. p., but if we select a point 45° from this it is about 19.00 c. p.; if we try to do better and take the mean horizontal candle-power then it is 16.46 c. p., or if we wish to take the mean spherical candle-power we find it to be 13.25 c. p. The watts in all cases being 79.58, we can sell this lamp as either 7.71, 4.09, 4.84, or 6.00 watts per candle.

It is, I think, commonly understood that the lamps of the Edison company are rated according to the following definition of a 16 c. p. lamp. A new 16 c. p. lamp will, when run at the number of Legal volts indicated by the number on its base, give out light which, at a point on the horizontal circle 45° from the shanks, will be equal to 16 standard candles. This one point is taken to represent the mean horizontal

candle-power. It will be noticed that the Edison lamps tested come fairly close to this rating, and also that the other lamps do not, indicating that the other makers do not understand a 16 c. p. lamp to be the same thing that the Edison company do.

It would be a great advantage to all parties if some authoritative statement of what is meant by the candle-power of an incandescent lamp could be made, and thus settle at once the uncertainty now existing.

ROGERS LABORATORY OF PHYSICS,
Mass. Inst. of Technology, December, 1889.

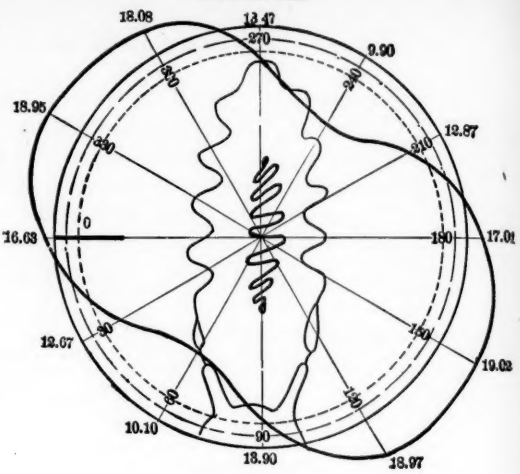
Plate I. — Data and Plots of Various Incandescent Lamps.

Lamp. — Weston, 70 volt. 16 c. p.
Mean standard reading = 16.63.
Mean spherical c. p. = 14.25.
Spherical reduction factor = 0.857.
Mean horizontal c. p. = 15.13.
Horizontal reduction factor = 0.909.
Mean sph. c. p. ÷ mean hor. c. p. = 0.942.
Volts = 69.96.
Amperes = 1.021.
Watts = 71.43.
Watts per mean sph. c. p. = 5.01.
Watts per mean hor. c. p. = 4.72.
Rated c. p. = full circle.
Mean sph. c. p. = dotted circle.
Mean hor. c. p. = dashed circle.
Section of filament = ▬
Scale, 10 c. p. per inch.

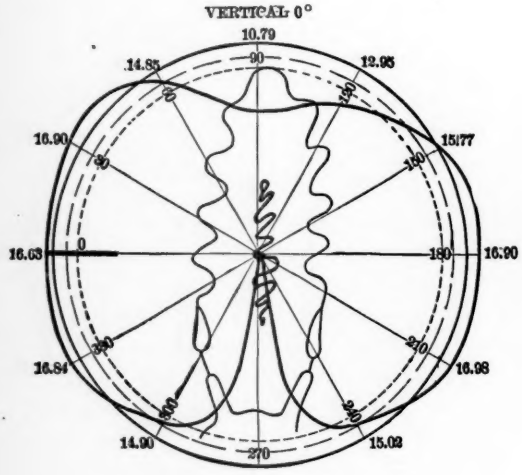
W. L. P.

Full circle reduced from 3.2″ to 2.5″ in engraving.

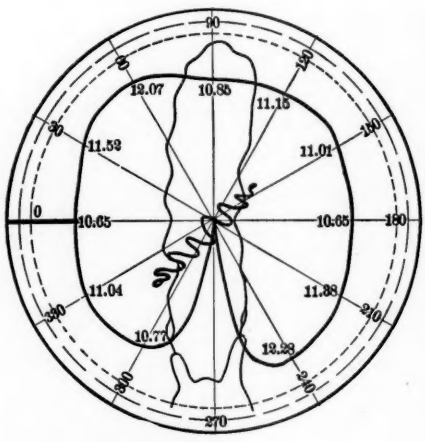
HORIZONTAL



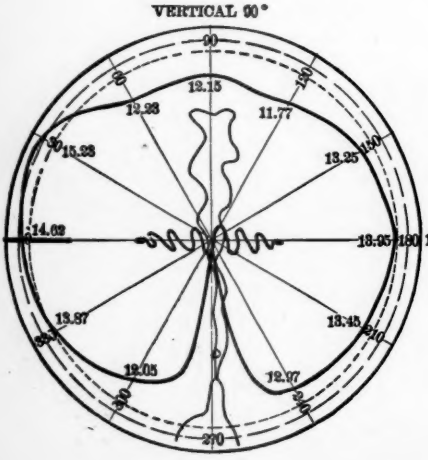
VERTICAL 0°



VERTICAL 45°



VERTICAL 90°



VERTICAL 135°

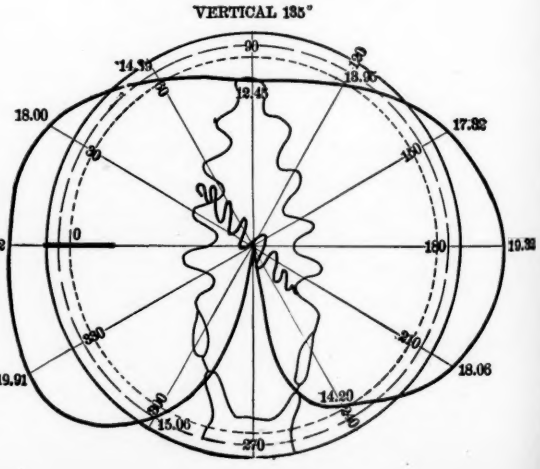


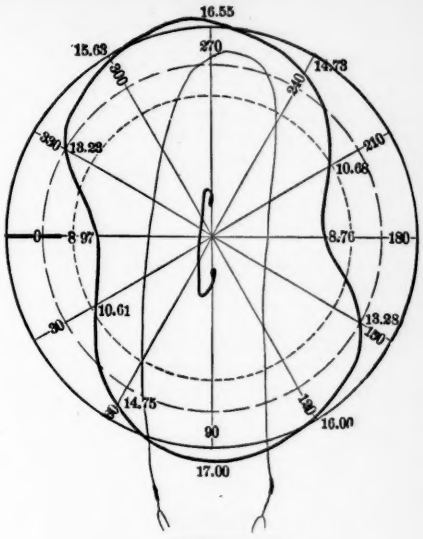
Plate II. — Data and Plots of Various Incandescent Lamps.

Lamp. — Weston, 110 volt. 16 c. p.
Mean standard reading = 8.97.
Mean spherical c. p. = 10.96.
Spherical reduction factor = 1.222.
Mean horizontal c. p. = 13.37.
Horizontal reduction factor = 1.491.
Mean sph. c. p. ÷ mean hor. c. p. = 0.820.
Volts = 110.1.
Amperes = 0.530.
Watts = 58.36.
Watts per mean sph. c. p. = 5.32.
Watts per mean hor. c. p. = 4.36.
Rated c. p. = full circle.
Mean sph. c. p. = dotted circle.
Mean hor. c. p. = dashed circle.
Section of filament = ▬
Scale, 10 c. p. per inch.

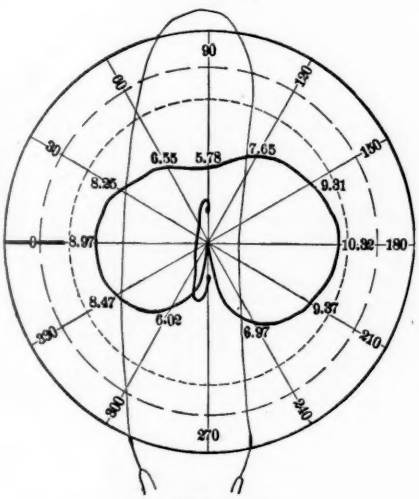
W. L. P.

Full circle reduced from 3.2″ to 2.5″ in engraving.

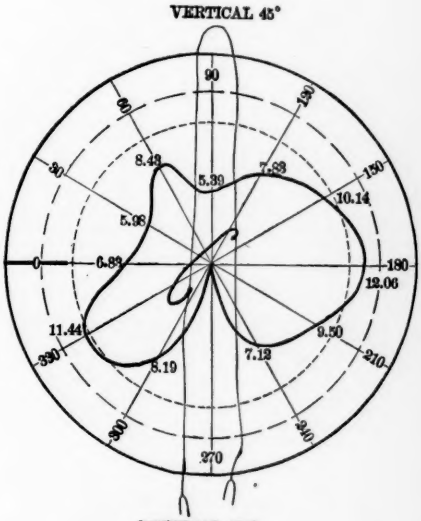
HORIZONTAL



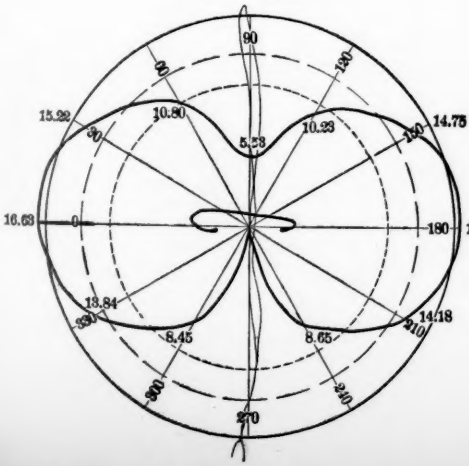
VERTICAL 0°



VERTICAL 45°



VERTICAL 90°



VERTICAL 135°

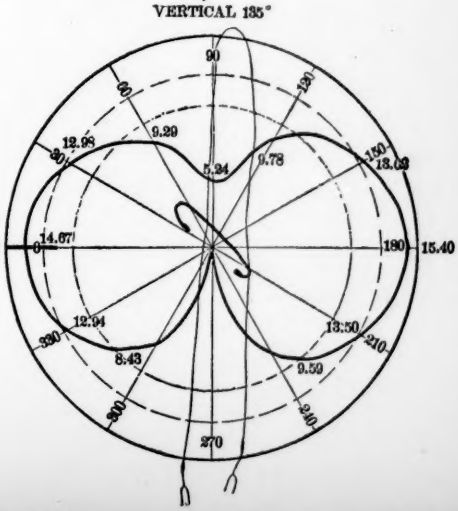


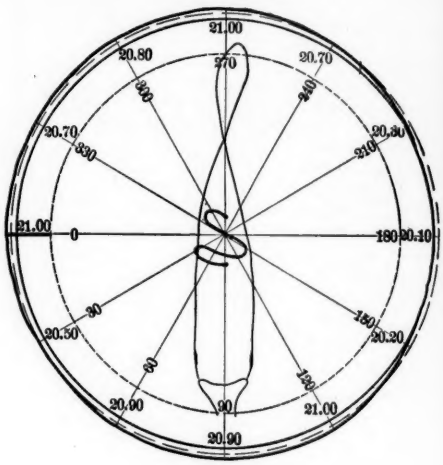
Plate III. — Data and Plots of Various Incandescent Lamps.

Lamp. — Thomson-Houston, 52.6 volt. 20 c. p.
Mean standard reading = 21.00.
Mean spherical c. p. = 16.82.
Spherical reduction factor = 0.801.
Mean horizontal c. p. = 20.68.
Horizontal reduction factor = 0.985.
Mean sph. c. p. ÷ mean hor. c. p. = 0.813.
Volts = 52.61.
Amperes = 1.250.
Watts = 65.76.
Watts per mean sph. c. p. = 3.91.
Watts per mean hor. c. p. = 3.18.
Rated c. p. = full circle.
Mean sph. c. p. = dotted circle.
Mean hor. c. p. = dashed circle.
Section of filament = ●
Scale, 10 c. p. per inch.

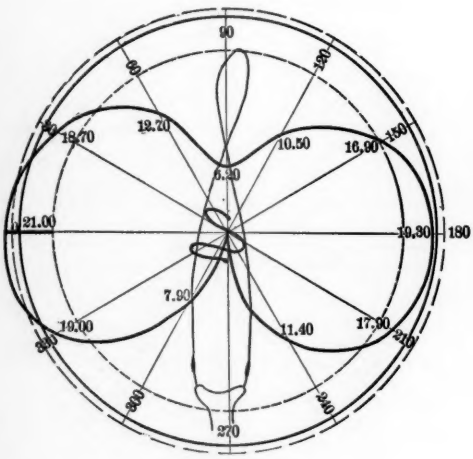
W. L. P.

Full circle reduced from 3.2″ to 2.5″ in engraving.

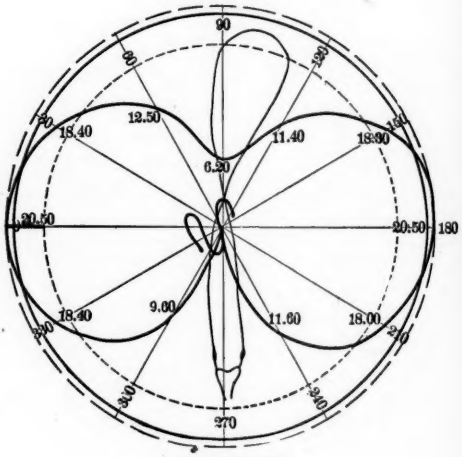
HORIZONTAL



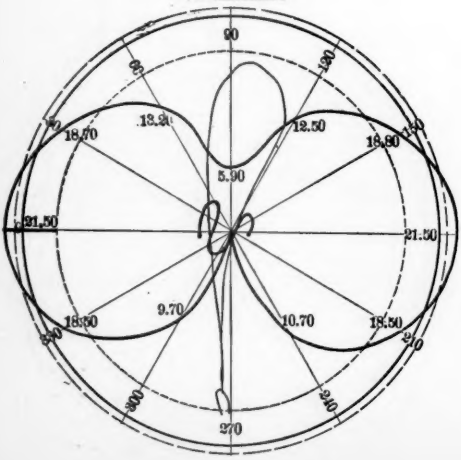
VERTICAL 0°



VERTICAL 45°



VERTICAL 90°



VERTICAL 135°

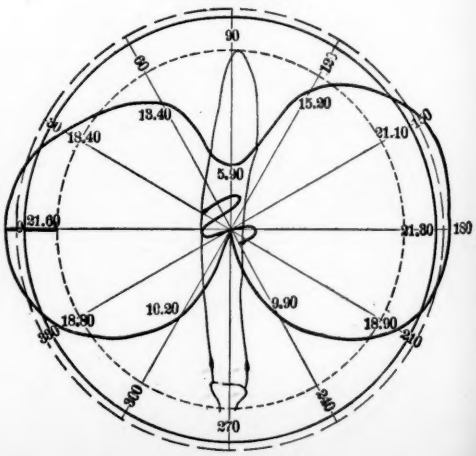


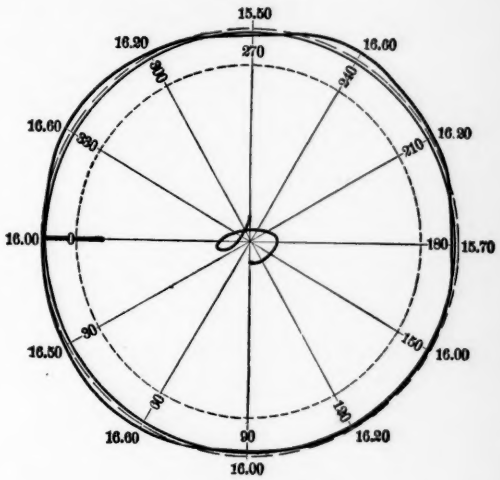
Plate IV. — Data and Plots of Various Incandescent Lamps.

Lamp. — Thomson-Houston, 75 volt. 16 c. p.
Mean standard reading = 16 00.
Mean spherical c. p. = 13.31.
Spherical reduction factor = 0.832.
Mean horizontal c. p. = 16.18.
Horizontal reduction factor = 1.011.
Mean sph. c. p. ÷ mean hor. c. p. = 0.823.
Volts = 74.98.
Amperes = 0.705.
Watts = 52.87.
Watts per mean sph. c. p. = 3.97.
Watts per mean hor. c. p. = 3.27.
Rated c. p. = full circle.
Mean sph. c. p. = dotted circle.
Mean hor. c. p. = dashed circle.
Section of filament = ●
Scale, 10 c. p. per inch.

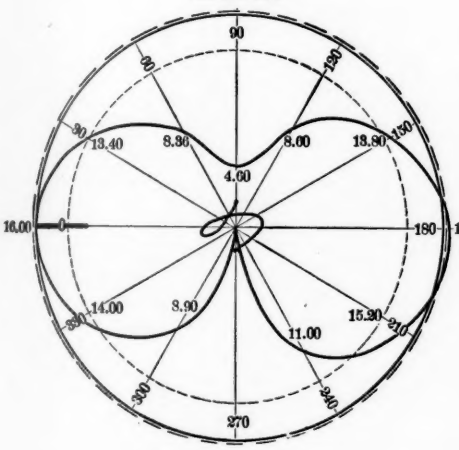
W. L. P.

Full circle reduced from 3.2″ to 2.5″ in engraving.

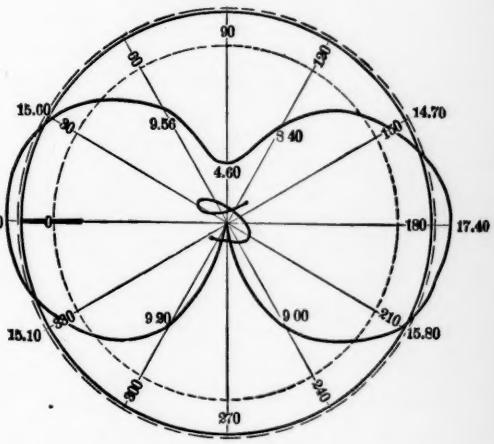
HORIZONTAL



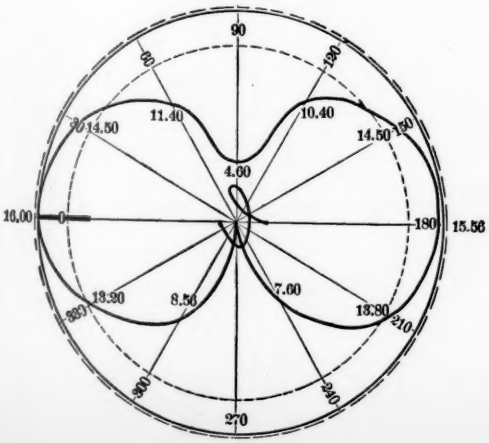
VERTICAL 0°



VERTICAL 45°



VERTICAL 90°



VERTICAL 135°

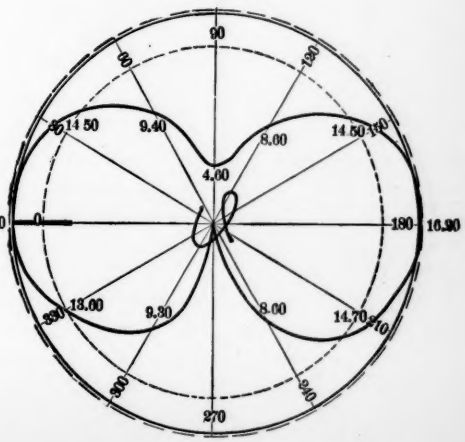


Plate V. — Data and Plots of Various Incandescent Lamps.

Lamp. — Thomson-Houston, 110 volt. 16 c. p.
Mean standard reading = 13.00.
Mean spherical c. p. = 10.50.
Spherical reduction factor = 0.808.
Mean horizontal c. p. = 12.86.
Horizontal reduction factor = 0.990.
Mean sph. c. p. ÷ mean hor. c. p. = 0.816.
Volts = 110 1.
Amperes = 0.472.

Watts = 51.96.
Watts per mean sph. c. p. = 4.95.
Watts per mean hor. c. p. = 4.04.
Rated c. p. = full circle.
Mean sph. c. p. = dotted circle.
Mean hor. c. p. = dashed circle.
Section of filament = ●
Scale, 10 c. p. per inch.

W. L. P.

Full circle reduced from 3.2″ to 2.5″ in engraving.

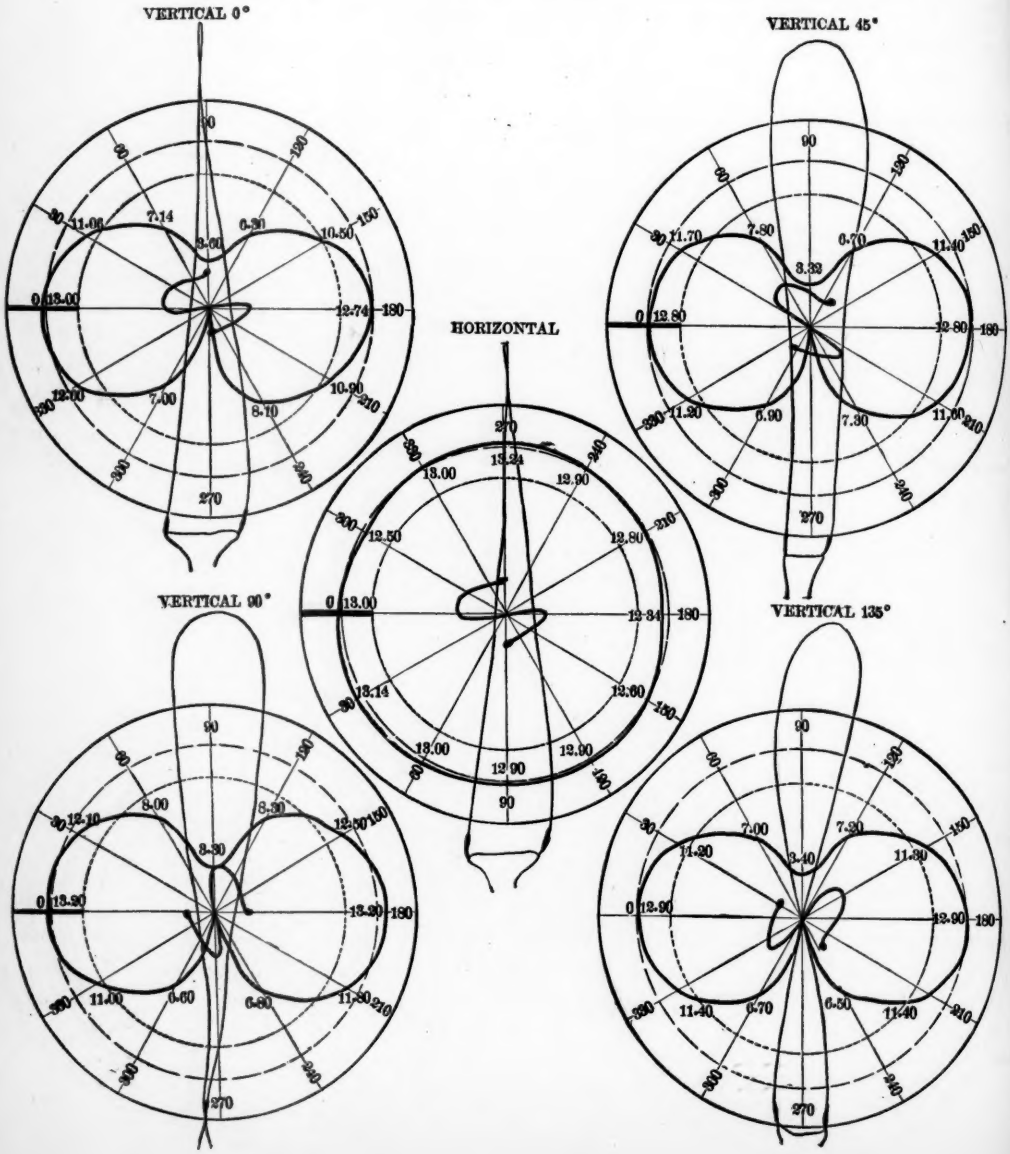
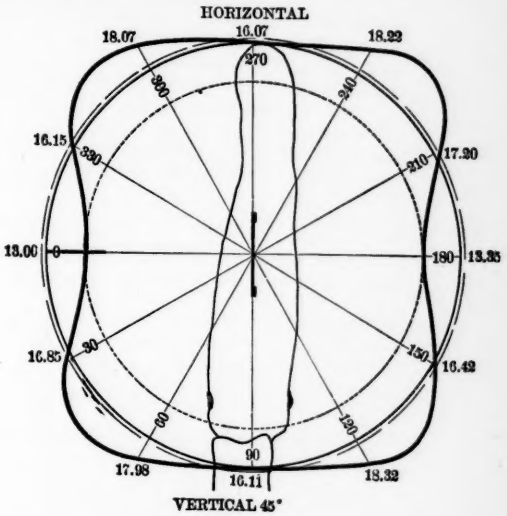


Plate VI. — Data and Plots of Various Incandescent Lamps.

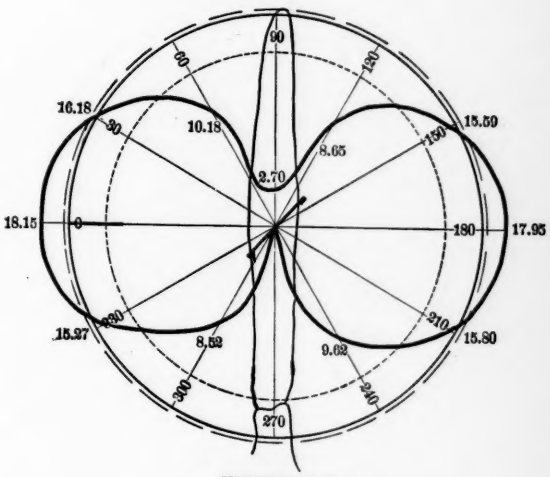
Lamp. — Edison, 101 volt. 16 c. p.
Mean standard reading = 13.00.
Mean spherical c. p. = 13.25.
Spherical reduction factor = 1.02.
Mean horizontal c. p. = 16.46.
Horizontal reduction factor = 1.27.
Mean sph. c. p. ÷ mean hor. c. p. = 0.805.
Volts = 100.9.
Amperes = 0.789.
Watts = 79.58.
Watts per mean sph. c. p. = 6.00.
Watts per mean hor. c. p. = 4.84.
Rated c. p. = full circle.
Mean sph c. p. = dotted circle.
Mean hor. c. p. = dashed circle.
Section of filament = ■
Scale, 10 c. p. per inch.

W. L. P.

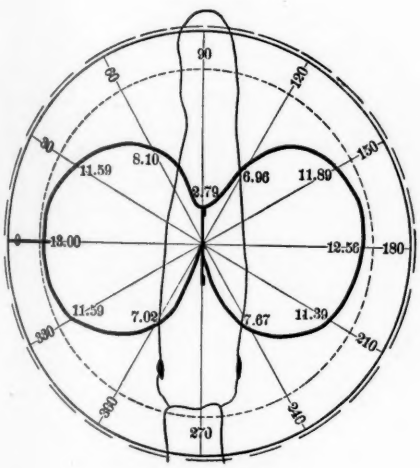
Full circle reduced from 3.2″ to 2.5″ in engraving.



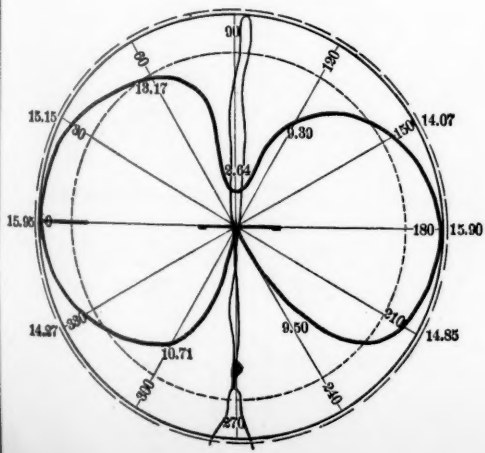
VERTICAL 45°



VERTICAL 0°



VERTICAL 90°



VERTICAL 135°

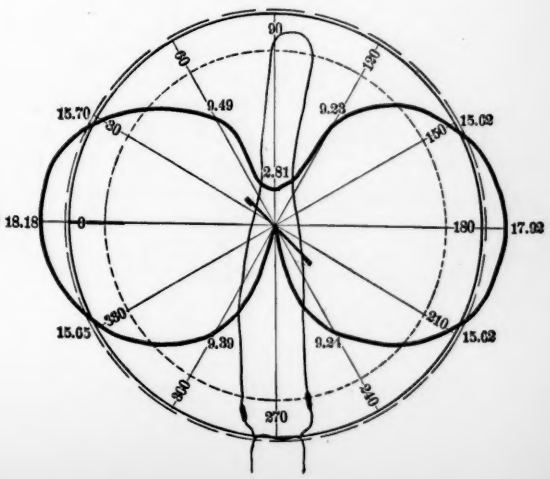


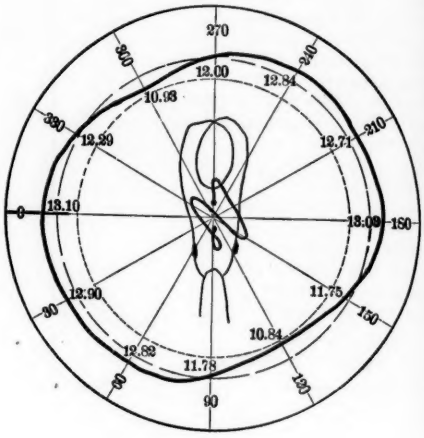
Plate VII. — Data and Plots of Various Incandescent Lamps.

Lamp. — Swan, 38 volt. 16 c. p.
Mean standard reading = 13.10.
Mean spherical c. p. = 10.57.
Spherical reduction factor = 0.807.
Mean horizontal c. p. = 12 25.
Horizontal reduction factor = 0.937.
Mean sph. c. p. ÷ mean hor. c. p. = 0.863.
Volts = 38.05.
Amperes = 1.30.
Watts = 49.65.
Watts per mean sph. c. p. = 4.70.
Watts per mean hor. c. p. = 4.05.
Rated c. p. = full circle.
Mean sph. c. p. = dotted circle.
Mean hor. c. p. = dashed circle.
Section of filament = ●
Scale, 10 c. p. per inch.

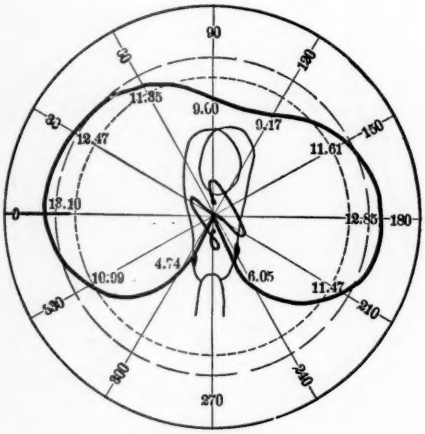
W. L. P.

Full circle reduced from 3.2″ to 2.5″ in engraving.

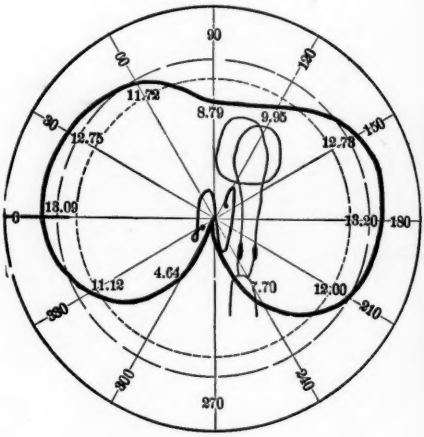
HORIZONTAL



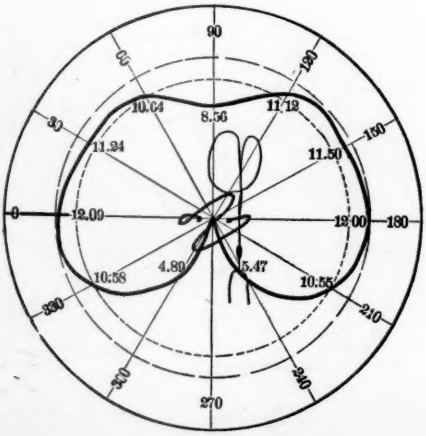
VERTICAL 0°



VERTICAL 45°



VERTICAL 90°



VERTICAL 135°

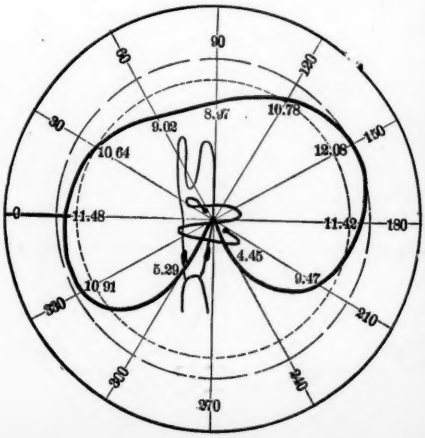
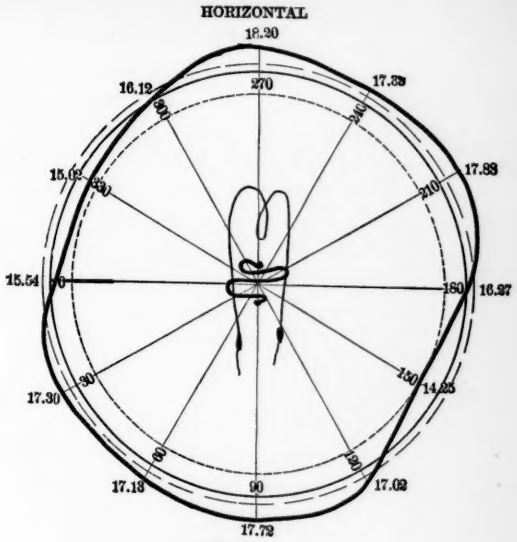


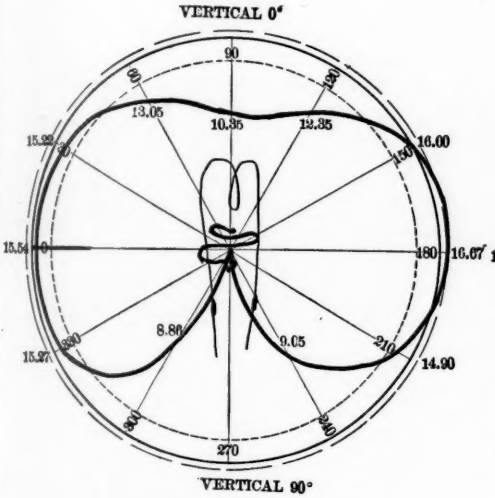
Plate VIII. — Data and Plots of Various Incandescent Lamps.

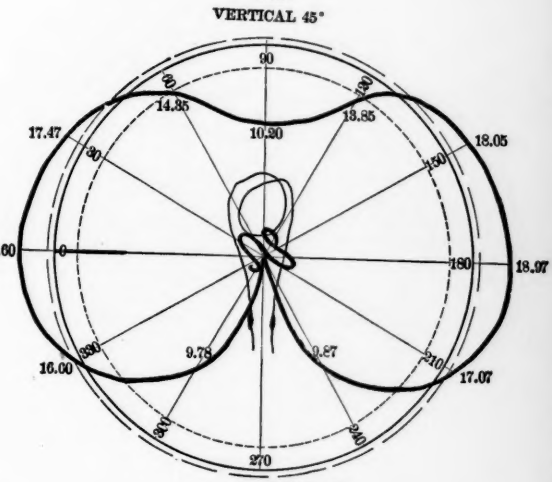
Lamp. — Swan, 46 volt. 16 c. p.
Mean standard reading = 15.54.
Mean spherical c. p. = 14.38.
Spherical reduction factor = 0.925.
Mean horizontal c. p. = 16.73.
Horizontal reduction factor = 1.077.
Mean sph. c. p. ÷ mean hor. c. p. = 0.859.
Volts = 45.99.
Amperes = 1.113.
Watts = 51.18.
Watts per mean sph. c. p. = 3.56.
Watts per mean hor. c. p. = 3.06.
Rated c. p. = full circle.
Mean sph. c. p. = dotted circle.
Mean hor. c.p. = dashed circle.
Section of filament = ●
Scale, 10 c. p. per inch.

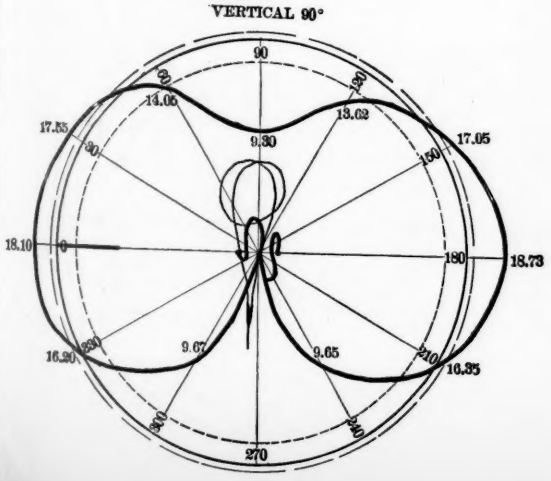
W. L. P.

Full circle reduced from 3.2″ to 2.5″ in engraving.









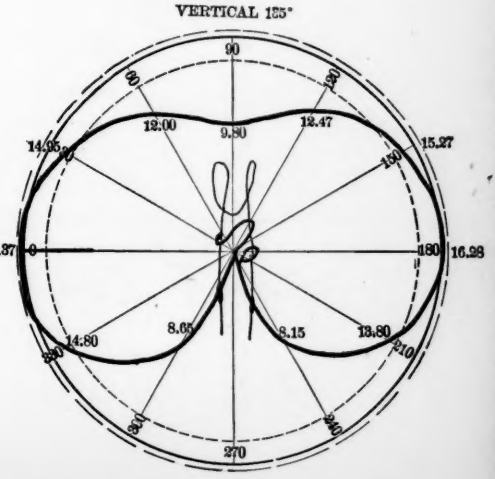


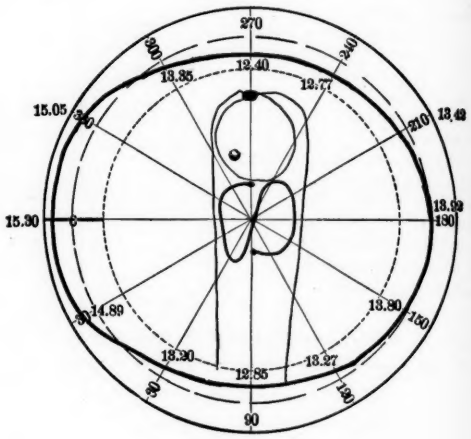
PLATE IX. — DATA AND PLOTS OF VARIOUS INCANDESCENT LAMPS.

Lamp. — Swan, 92 volt. 16 c. p.
Mean standard reading = 15.30.
Mean spherical c. p. = 11 49.
Spherical reduction factor = 0.751.
Mean horizontal c. p. = 14.00.
Horizontal reduction factor = 0.915.
Mean sph. c. p. ÷ mean hor. c p. = 0.821.
Volts = 91.98.
Amperes = 0.594.
Watts = 54.64.
Watts per mean sph. c. p. = 4.76.
Watts per mean hor. c. p. = 3.90.
Rated c. p. = full circle.
Mean sph. c. p. = dotted circle.
Mean hor. c. p. = dashed circle.
Section of filament = ●
Scale 10 c. p. per inch.

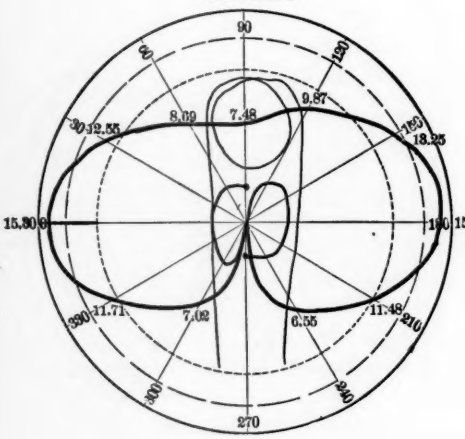
W. L. P.

Full circle reduced from 3 2″ to 2 5″ in engraving.

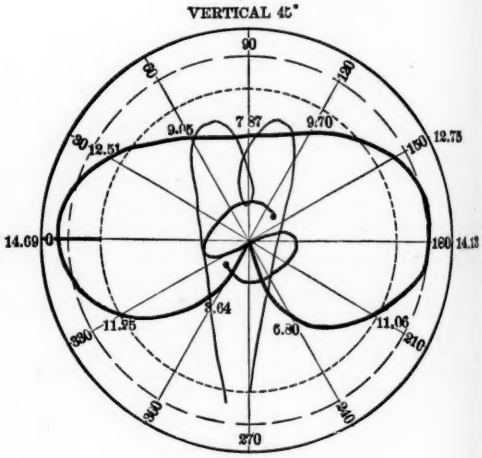
HORIZONTAL



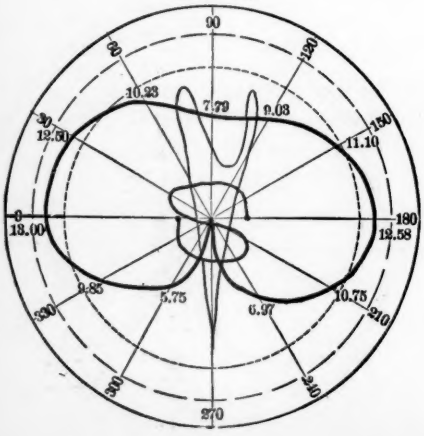
VERTICAL 0°



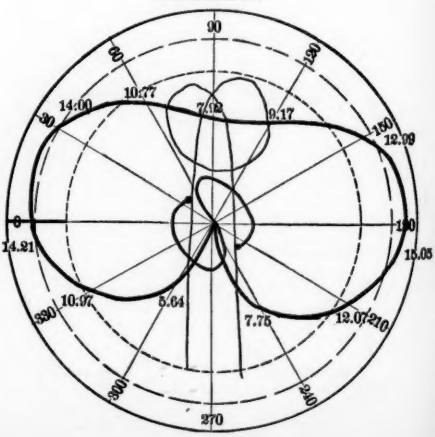
VERTICAL 45°



VERTICAL 90°



VERTICAL 135°



AN EXPERIMENTAL STUDY OF THE ERRORS OF DIFFERENT TYPES OF CALORIMETERS.[1]

BY CECIL H. PEABODY, ASSOCIATE PROFESSOR OF STEAM ENGINEERING, AND ARTHUR L. WILLISTON, S. B.

THIS paper gives the results of some experiments on calorimeters for determining the moisture in steam, made by Mr. Williston in the laboratories of the Massachusetts Institute of Technology in the preparation of his graduation thesis. The object of the experiments was to determine the nature, magnitude, and causes of errors in calorimeters of different types, and to find how to avoid them, or how to correct them if unavoidable.

Four forms of calorimeters were used in the experiments:

(1) a throttling calorimeter designed by the writers;
(2) a Barrus continuous water calorimeter;
(3) a Hoadley calorimeter;
(4) a barrel calorimeter.

The throttling calorimeter consists of a chamber, into which steam is admitted through a throttle valve, and from which it escapes through a larger valve. The steam is superheated by the throttling or wire-drawing, and its condition can be entirely determined by the temperature and pressure, which are taken by a thermometer and pressure gauge. The pressure of the steam in the main steam pipe from which the sample is taken is also observed. The calorimeter and the pipe and valve leading to it are well wrapped with non-conducting material, to prevent radiation. If it be assumed that no heat is lost by the steam, the heat in one pound will be the same in the calorimeter as in the main steam pipe, and we have the equation

$$xr + q = \lambda_c + c_p(t_s - t_c), \qquad (1)$$

in which x is the part of one pound of fluid in the steam pipe that is steam, $1 - x$ being water; r is the heat of vaporization, and q the heat of the liquid at boiler pressure; λ_c is the total heat, and t_c the temperature of saturated steam at the pressure in the calorimeter; t_s is the

[1] Presented at the Twentieth Meeting of the American Society of Mechanical Engineers, New York, 1889.

temperature of the superheated steam in the calorimeter; and c_p is the specific heat of superheated steam at constant pressure (0.48 nearly). From the equation (1), the values of x and $1 - x$ are readily found by the aid of a table of the properties of saturated steam.

The Barrus calorimeter consists essentially of a straight vertical tube running through an open wooden bucket, and forming a small surface condenser. The condensed steam is collected at the bottom of the tube, cooled and weighed. The condensing water is let in so as to circulate round the tube, is then mixed and drawn off, and weighed separately. The pressure of the steam is observed, and the temperatures of the condensed water and of the cold and warm condensing water are taken. Let the weight of the condensed water be w, and of the condensing water W; let r be the heat of vaporization, and q the heat of the liquid, of steam at the pressure in the supply pipe; let q_3 be the heat of the liquid at the temperature of the water resulting from the condensation of steam, collected at the bottom of the vertical tube before it is passed through the cooler, and let q_1 and q_2 be the heats of the liquid corresponding to the initial and final temperatures of the condensing water. Then the quality of the steam, x, and the amount of priming, $1 - x$, may be calculated by the equation

$$w(xr + q - q_3) = W(q_2 - q_1) + e, \qquad (2)$$

in which e is the heat lost by external radiation, to be determined by a special experiment.

The Hoadley calorimeter is non-continuous, and consists of a surface condenser of thin copper to which steam is admitted, and in which it is collected, placed in a thin copper cylinder containing the condensing water, and thoroughly wrapped, lagged, and jacketed with eider-down and hair-felt in spaces formed by three concentric galvanized iron cylinders. Arrangements are made for stirring the condensing water and for taking the mean temperature. The calorimeter is placed on a special platform scale, so that weights may be taken of the calorimeter, (1) when empty; (2) when the cooling water is run in; (3) when steam has been admitted, condensed, and collected in the surface condenser. The condensed water may also be drawn off and weighed separately, but not satisfactorily, as more or less water will adhere to the sides of the condenser. The equation given for this case is

$$w(xr + q - q_2) = (W + W')(q_2 - q_1) + e, \qquad (3)$$

in which w and W are the weights of the condensed steam and condensing water, and W' is the water equivalent of the copper forming

the condenser and calorimeter; r is the heat of vaporization, and q the heat of the liquid corresponding to the pressure of the sample of steam; q_1 and q_2 are the initial and final temperatures of the cooling water; and e is the external radiation, while x is the quality of the steam, and $1 - x$ is the amount of priming.

The barrel calorimeter was a wooden barrel set on scales, with pipes and valves for supplying cold water and steam, and with a large valve for rapidly emptying the barrel at the end of a test. The temperature of the cold water was taken before it entered the barrel, and the correction for radiation and the water equivalent of the barrel avoided by first filling the barrel with hot water, at about the temperature of the contents of the barrel at the end of the test, and then emptying rapidly and filling with cold water for the test. The equation for this case, using the same notation as in the preceding equations, is

$$w(xr + q - q_2) = W(q_2 - q_1). \qquad (4)$$

At the suggestion of the writer, the calorimeters were supplied with superheated steam, for which the condition could be known from the temperature and pressure, provided that Regnault's value of the specific heat c_p may be assumed to be true at all temperatures and pressures. In most of these tests the steam was superheated only a small amount to avoid uncertainty from this source. If λ is the total heat and the temperature of saturated steam at the pressure in the supply pipe, and if t'_s is the temperature of the superheated steam in that pipe, then equations (1), (2), (3), and (4) become

$$\lambda + c_p(t'_s - t) = \lambda_c + c_p(t_s - t_c), \qquad (5)$$

$$w\{(\lambda - q_3) + c_p(t'_s - t)\} = W(q_2 - q_1) + e, \qquad (6)$$

$$w\{(\lambda - q_2) + c_p(t_s - t)\} = (W + W')(q_2 - q_1) + e, \qquad (7)$$

$$w\{(\lambda - q_2) + c_p(t'_s - t)\} = W(q_2 - q_1). \qquad (8)$$

1. Throttling Calorimeter.

The errors of this calorimeter are of two sorts, — those arising from inaccuracies of the thermometer or the gauge, which can be calculated, and those, like the error from radiation, which cannot be calculated.

In the description previously given, it was pointed out that small inaccuracies of thermometer or gauge had slight effect on the indications of this calorimeter. Thus, at one hundred pounds' pressure absolute, an error of one pound in pressure giving apparently one hundred and one

pounds will make the priming appear to be from 0.02 to 0.03 of one per cent larger than it really is. At fifty pounds absolute the error may be twice as much. On the other hand, an error of one pound in the reading of the calorimeter gauge may give an error of 0.2 of one per cent when the pressure is five pounds absolute, and an error of 0.025 when the pressure is thirty-five pounds absolute. An error of one degree in the thermometer may give an error of 0.025 of one per cent.

Two series of tests were made on this calorimeter, using superheated steam; the first, for which the results are given in Table I., to determine the effect of varying degrees of throttling and superheating, and the second, for which the results are given in Table II., to determine the effect of running varying amounts of steam through the calorimeter.

TABLE I. — THROTTLING CALORIMETER.

	Pressure absolute in supply pipe, pounds.	Pressure absolute in calorimeter, pounds.	Temperature F. in supply pipe.	Temperature F. in calorimeter.	Superheating in supply pipe.	Superheating in calorimeter.	Loss in thermal units per pound of steam used.
1	80.2	19.9	316.2	280.2	4.2	52.4	2.6
2	80.6	23.5	317.4	285.2	5.4	48.4	2.5
3	80.3	28.4	318.0	288 1	5.9	40.9	3.0
4	79.8	32.7	318.4	290.5	6 8	35.3	3.6
5	80.8	37.5	318.5	293.4	6.0	30 1	3.4
6	87.4	24.1	353 1	318.0	35.1	100.0	6.8
7	87.4	29.2	350.6	342.0	32 6	93.3	8.0
8	87.2	34.5	350.1	344.0	32 3	85.7	7.4
9	87.2	39.3	348.8	345.4	31.0	79.3	7.5

The first five tests were made with just enough superheating in the supply pipe to determine the quality of the steam, and with as nearly as possible the same quantity of steam flowing through the calorimeter per minute.

The last four tests were made with a considerable amount of superheating in the supply pipe, and with, also, a varying degree of throttling. The loss of heat per pound is about double that in the preceding set of tests, but this is due to the fact that less steam per minute was run through the calorimeter; the radiation, though larger, could not have been twice as great as in the preceding case. Each set of tests, considered by itself, shows that the effect of varying degrees of throttling has a very small influence on the result, the greatest variation in

the loss for either group being 1.2 thermal units, or about one tenth of one per cent.

TABLE II. — THROTTLING CALORIMETER.

	Pressure absolute in supply pipe, pounds.	Pressure absolute in calorimeter, pounds.	Temperature F. in supply pipe.	Temperature F. in calorimeter.	Superheating in supply pipe.	Superheating in calorimeter.	Weight of steam used per hour, pounds.	Loss in thermal units per pound of steam.	Loss in thermal units per hour.	Loss per hour per degree of difference of temperature between calorimeter and air.	Error in priming from loss by radiation, per cent.
	1	2	3	4	5	6	7	8	9	10	11
1	88.0	25.0	429.8	361.0	111.3	121.0	43.5	19.3	850	2.4	2.2
2	88.0	24.9	410.5	353.1	92.0	113.3	54.0	12.8	690	2.0	1.5
3	87.0	25.0	390.2	349.2	72.5	109.2	69.0	6.4	442	1.5	0.7
4	87.4	24.9	390.2	350.2	72.2	110.4	70.5	5.5	388	1.3	0.6
5	87.5	24.9	384.8	346.1	66 7	106.3	75.0	4.9	368	1.2	0.5
6	86.1	24.9	374.4	340.5	57.5	100.7	90.0	2.8	352	0.9	0.3
7	85.7	25.0	361.9	329.2	45.3	89.2	102.0	2.3	233	0.8	0.2
8	85.2	24.9	350.4	320.7	34.2	80.9	135.0	0.9	122	0.4	0.1
9	84.0	25.0	343.6	314.4	28.4	74.4	137.0	0.9	123	0.4	0.1
10	78.0	25 0	330.4	303.1	20.4	63.1	201.0	0.9	181	0.8	0.1

An examination of Table II. shows that the greatest error of this calorimeter comes from radiation, and that for small quantities of steam per hour, the error may be 2.2 per cent. But the table also shows that the error may be reduced to one tenth of one per cent by the simple expedient of running a sufficient quantity of steam per hour. For the calorimeter used, which was four inches in diameter and ten inches long, at least 120 pounds of steam per hour should be used. As the calorimeter has been made with a simple valve for admitting steam, there is no way of knowing how much steam is used except by condensing and weighing it. In the future it is proposed that these calorimeters shall be provided with rounded orifices of suitable size for giving the proper quantity of steam per hour. The diameter of the orifice may be calculated with sufficient accuracy by the following formula given by Napier:

$$G = \frac{p}{70} F,$$

in which G is the flow of steam per second for the area F in square inches, and p is the absolute pressure above the orifice in pounds per

square inch. For the calorimeter used in these tests, the orifice should be about 0.2 of an inch in diameter.

The greatest defect in this type of calorimeter has been shown to be that the steam will not be superheated by throttling if the priming is more than a certain per cent, depending on the pressure of the steam. This defect may perhaps be remedied by letting the steam flow through a priming box with provision for withdrawing and measuring the water that collects in it, from which box the steam can flow through an orifice to the superheating chamber. In such case the flow through the orifice must be determined by special experiment, as the tests on flow of steam presented at this meeting show that Napier's formula may be in error to the extent of two per cent.

2. The Barrus Calorimeter.

With this type of calorimeter accurate instruments and a very considerable degree of care and skill are required, to give good results. Thus, an error of one hundredth of a degree F. in the temperature of the cooling water, whether cold or warm, will produce an error of one thirtieth of one per cent in the result. An error of one degree in the temperature of the condensed steam will affect the result by one tenth of one per cent. It appears that a good thermometer will answer for the latter, but that for the former an exceptionally good thermometer must be used, and that changes of the freezing point are to be guarded against. An error in the steam pressure is not much more serious than for the throttling calorimeter. The greatest difficulty is in determining the weight of the condensed steam and of the cooling water. An error of one hundredth of a pound in the determination of the condensed steam will cause an error of one tenth of one per cent in the result in a test of twenty minutes' duration. A slight difference of level of the water in the glass water-gauge on the pipe draining the condensing pipe will make such a difference in weight, but this error is constant, and the per cent of error can be reduced by a longer test. Common platform scales are commonly used for weighing the condensing water, and they are liable to an error of half a pound, which for a test of twenty minutes will give an error of fifteen hundredths of a per cent in the result.

In Table III. are given the data and results of tests, twenty minutes in duration, on a calorimeter of this type when supplied with superheated steam. The small differences between the heat supplied and

the heat accounted for show that the calorimeter is capable of good work, and that it is not necessary to correct for radiation.

TABLE III. — THE BARRUS CALORIMETER.

	Boiler pressure, absolute, pounds.	Temperature F. of superheated steam.	Temperature F. of cold condensing water.	Temperature F. of warm condensing water.	Temperature F. of condensed steam.	Weight of steam, pounds.	Weight of condensing water.	Heat acquired by condensing water per pound of steam.	Heat yielded by one pound of steam.	Difference in B. T. U.	Error in priming, per cent.
1	87.1	344.3	53.26	85.58	306.9	331.5	11.72	912.7	915.1	+2.4	+0.25
2	87.5	363.4	53.53	85.81	309.8	329.25	11.56	917.6	921.4	+3.8	+0.4
3	87.7	362.8	53.28	85.77	311.0	393.5	9.82	969.6	967.8	−1.8	−0.2
4	89.3	414.1	54.83	86.86	310.8	328.5	11.114	945.2	944.4	−0.8	−0.1
5	89.0	404.2	53.38	86.98	307.7	336.13	11.27	941.9	942.8	+0.9	+0.1
6	88.3	405.5	55.38	86.81	311.7	335.25	11.17	441.2	939.6	−1.6	−0.2
7	88.8	402.1	55.19	87.03	311.5	337.0	11.36	940.8	937.9	−2.9	−0.3
8	88.6	406.2	55.24	86.96	311.9	334.25	11.21	942.4	939.6	−2.8	−0.3
9	89.1	412.9	55.26	86.79	310.7	335.3	11.12	445.4	943.9	−1.5	−0.2
10	89.0	417.0	55.44	87.12	311.9	333.5	11.11	947.7	944.7	−3.0	−0.3

3. THE HOADLEY CALORIMETER.

With this calorimeter, an error of one hundredth of a degree in the temperature of the condensing water will cause an error of 0.04 of one per cent in the result. An error of one pound in the weight of the condensing water will cause an error in the result of 0.5 of one per cent, while an error of one tenth of a pound in the weight of the condensed steam may give an error of two per cent. The difficulty and uncertainty of drawing this water off, and of weighing it separately, is the most objectionable feature of this calorimeter.

In testing this calorimeter with superheated steam, the supply was constant, and during the intervals of a series of tests, it was diverted into a condenser to dispose of it. The data and results of the tests are given in Table IV. The water equivalent of the copper forming the calorimeter and surface condenser was determined by Mr. Hoadley to be 17.2 pounds, and is included in the weights of condensing water given.

TABLE IV. — THE HOADLEY CALORIMETER.

	Pressure of steam, absolute, pounds.	Temperature F. of superheated steam.	Superheating in supply pipe, degrees F.	Temperature F. of cold condensing water.	Temperature F. of warm condensing water.	Weight of condensing water.	Weight of condensed steam.	Gain in B. T. U. per pound of condensing water.	Gain in B. T. U. by condensing water per pound of steam.	Loss in B. T. U. by each pound of steam.	Difference in B. T. U.	Error in priming, per cent.
1	72.3	337.1	32.15	54.44	78.60	225.7	4.30	22.15	1155.2	1143.8	−11.4	−1.2
2	81.2	353.8	41.0	58.32	81.65	227.0	4.60	23.29	1149.7	1147.4	− 2.3	−0.2
3	70.1	333.0	30.2	59.74	85.56	225.2	5.10	25.78	1139.5	1135.2	− 4.3	−0.5
4	84.6	345.3	29.6	58.86	84.80	224.0	5.15	25.89	1130.0	1139.5	+ 9.5	+1.0
5	76.3	344.8	36.3	62.03	79.22	227.6	3.40	17.16	1145.3	1146.0	+ 0.7	+0.1
6	77.5	348.4	38.8	58.70	85.05	224.6	5.19	26.29	1139.9	1141.8	+ 1.9	+0.2
7	76.5	346.6	37.9	59.41	83.21	226.4	4.75	23.75	1132.0	1142.9	+10.9	+1.2
8	76.0	345.7	37.4	59.81	84.47	224.5	4.80	24.72	1150.1	1141.3	− 8.8	−1.0
9	76.5	346.0	37.3	59.40	90.20	224.8	6.05	30.72	1139.8	1135.5	− 4.3	−0.5
10	78.0	350.2	40.1	59.71	80.30	227.3	5.32	26.53	1135.7	1141.3	+ 5.6	+0.6

4. BARREL CALORIMETER.

The tests given in Table V. were made on a barrel calorimeter for the sake of comparison with the tests on the calorimeters of other types. They were made with care, and may be considered to give the degree of accuracy attainable in engineering work.

TABLE V. — BARREL CALORIMETER.

	Pressure absolute in steam pipe, pounds.	Temperature F. superheated steam.	Superheating of steam in supply pipe, degrees F.	Temperature of cold water, degrees F.	Temperature of warm water, degrees F.	Weight of condensing water, pounds.	Weight of condensed steam, pounds.	Gain of B. T. U. per pound of condensing water.	Gain in B. T. U. per pound of steam by condensing water.	Loss of B. T. U. by each pound of steam.	Difference in B. T. U.	Error in priming, per cent.
1	81.0	351.9	39.2	56.50	91.50	312.6	9.5	24.61	1143.0	1136.6	− 6.4	−0.7
2	73.7	338.9	32.7	56.43	91.20	311.8	9.6	24.54	1122.8	1131.8	+ 9.0	+1.0
3	79.4	347.6	36.2	56.38	88.50	320.0	9.1	24.49	1127.4	1138.9	+11.5	+1.3
4	77.0	348.8	39.5	56.42	88.95	325.9	9.2	24.53	1146.7	1139.2	− 7.5	−0.8
5	75.5	345.2	37.4	56.45	88.05	317.3	8.7	24.56	1150.3	1137.7	−12.6	−1.4
6	76.2	347.6	39.1	56.49	90.40	324.2	9.5	24.60	1154.8	1136.1	−18.7	−2.1

THE DEVELOPMENT OF THE SYSTEM OF AMALGAMATION OF GOLD ORES AT PRESENT IN USE IN THE MINING LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BY ROBERT H. RICHARDS, PROFESSOR OF MINING AND METALLURGY.

IN the winter of 1872–73 the little five-stamp battery, which had been obtained from the Union Iron Company of San Francisco as a part of the first equipment of the Mining Laboratory, was run on small lots of ore, severally from North Carolina, Georgia, Colorado, and New Hampshire. After each run, the plates, of ordinary sheet copper coated with mercury, were scraped to clean off the amalgam which had accumulated during the run, and were then supposed to be ready for the next lot of ore.

After the last of the runs, the plates were scraped a second time, and more gold amalgam was obtained; a third scraping still yielded gold, and it was evident that in these runs North Carolina ores had been credited with Georgia gold, and Georgia ores with New Hampshire gold.

Thus, at the outset, there loomed up the great difficulty which besets all laboratory experiments; namely, the problem of how to make careful quantitative experiments with small-sized working machines. In 1876 the first new experiment was tried. Instead of the ordinary thick copper plates, the thinnest to be found in the market, about $\frac{1}{50}$ inch, were used; after each run the entire set was dissolved in sulphuric acid, and the whole of the gold recovered. This entirely overcame the first difficulty, which may be called the *overlapping error*, but at the cost of much trouble and expense, and it led to another and possibly a worse difficulty; namely, the error due to new plates, causing a great loss of gold in the tailings, and which has been called the *new plate error*. It is well known among mill men that a new copper plate, although coated with mercury, is not in the best condition to catch gold, and that a layer of gold amalgam must be formed before the plate can be considered at all reliable. In fact, no mine is willing to send ore to a mill which has just put in new plates; so that in many places it is counted as one of the regular expenses of starting a new mill to run one hundred or more

tons of gold ore, in order to charge the plates, before taking in custom work.

After many trials the method of preparing the plates with the addition of silver amalgam was adopted. This has given means for overcoming all difficulties, and has made possible the testing of gold ores by the ton in an accurate and efficient manner. It would seem that the method as worked out in the laboratory was equally well suited to large mills, and therefore a somewhat detailed account may be of value.

Soft copper plate $\frac{1}{16}$ inch thick, of the size required, is scrubbed with sand, sal-ammoniac, quicklime, and mercury until it is plated. Dilute nitrate of mercury will plate the copper far more quickly, and with less trouble, but not so permanently, so deeply, or so thoroughly. If very obstinate spots are found, dilute nitrate of mercury may be used; and if this fails, a plumber's scraper will remove the spot. When thoroughly plated and washed clean, the plates are dried carefully with cotton batting. Mercury is then sprinkled on through chamois skin, and distributed with cotton. This will give the plates a brilliant, mirror-like surface, which will remain for several days if water is kept off them. The least addition of water will very soon bring out the yellow stain which is the enemy of the amalgamator. This yellow stain is prevented on old plates by the coating of gold amalgam which has formed on their surfaces.

This difficulty, as well as the new plate error, is overcome in the mining laboratory method by the substitution of silver amalgam for gold amalgam. Silver amalgam is made by dissolving silver in nitric acid diluted with an equal weight of water, and then adding about ten times as much quicksilver as silver. The silver is all precipitated, making a pasty amalgam; the liquor, after standing over night, is then decanted, and the remaining amalgam washed thoroughly with water. If silver dollars are used, one will make amalgam enough to paint about four square feet of surface. This amalgam is dried and squeezed in chamois skin, to remove the excess of mercury, until it is of about the consistence of soft putty. It should then be applied dry to the bright plates with a flat hog's-bristle paste-brush. The amalgamated plates should be allowed to drain for at least twelve hours, to avoid, as far as possible, the presence of free mercury on the plates during the run, as it is liable to flour and be lost.

Silver amalgam is just as good a catcher of gold as gold amalgam, so far as we yet know. This layer of silver amalgam also overcomes the overlapping error, because the gold never comes to any considerable extent into contact with the copper plate; and hence, when the

plates are scraped off in the usual way, the silver amalgam practically carries with it the whole of the gold. The first two cleanings up will be diluted with silver as a matter of course, but after this no such trouble will ensue.

The Institute mill, at the time these investigations were made, was a five-stamp battery, with stamps weighing originally 55 pounds, $3\frac{1}{2}$-inch face of shoe and die, $9\frac{1}{2}$-inch drop, 88 drops per minute. It used about 34 kilos of water per minute, and stamped through a screen punched with holes $\frac{1}{50}$ inch in diameter. The discharge was on both sides,— that is, double issue. We amalgamated in the battery without battery plates. The plates were five in number; net length available for amalgamation 5 feet 6 inches each, or a total length of $27\frac{1}{2}$ feet, and width of 10 inches. The plates sloped $1\frac{3}{8}$ inches to the foot, and never gave much trouble from settling sand. This is the minimum slope at which we should dare to place them; $1\frac{1}{2}$ inches to the foot would be a better slope. The mercury trap at the end of the plates was a kind of quicksand apparatus, which allowed the mercury to discharge below as fast as it accumulated.

When cleaning up, the battery amalgam was kept by itself, and that from each one of the five plates by itself. This enabled us to see when and where the amalgamation took place. The sand was separated by a *spitzkasten* apparatus into sand and slimes. The sand was concentrated, and yielded concentration and tailings. Assays were then made of the original ore, the residue in the battery, concentrations, tailings, and slimes.

TABULAR STATEMENT OF THE PROCESS.

Ore,	Amalgams,	Battery,	Each parted by itself.
		1st plate,	
		2d plate,	
Mercury,		3d plate,	
		4th plate,	
Silver,		5th plate,	
		Mercury trap,	
	Sand or spitzkasten,	Slimes, for chlorination or other treatment.	
		Sand on table,	Concentration for chlorination or other treatment.
			Tailings, — waste.

Pure mercury was used in the battery, and hence this lot when assayed gave us the fineness of the gold in the ore.

Besides the above tests, a sample was always taken from the pulp as it came from the stamp-mill, and also as it came from the plates. These two samples were taken at the rate of $\frac{1}{4}$ litre (dipperful) every

fifteen minutes. They served to give additional testimony in regard to the working of the plates.

Four tests were made; two of them on a low-grade ore from New Hampshire; the others on an ore from Nova Scotia, which was sent to us through the kindness of Mr. J. Fraser Torrance.

I. The New Hampshire lot. This was composed mostly of quartz, stained yellow with iron rust, having cavities from which the iron pyrites had been dissolved. It contained a small percentage of pyrites, but no gold that was visible as we examined the heap. This lot also contained some fine mica-schist, which was probably from the wall-rock.

This lot of ore weighed 2021.6 kilos (4447.5 pounds). A sample of it yielded to fire assay $4.14 in gold to the ton of 2,000 pounds, reckoning gold at $20.67 per ounce troy. The total value, therefore, of the gold in this lot was $9.20.

The yield of gold in the different parts of the process was as follows: —

2021.6 kilos ore containing		$9.200
yielded products as follows:		
Gold immediately available.		
Battery amalgam	$4.573	
1st plate "	2.694	
2d plate "	.215	
3d plate "	.180	
4th plate "	.099	
5th plate "	.050	
Mercury trap amalgam	.038	
		7.849
Gold recoverable from pyrites.		
Pyrites concentrations 74 kilos	0.421	
Residue left in battery 11.75 kilos	0.227	
		0.648
Gold lost in tailings, both the weight and the contents were obtained by difference, weight = 1935.85 kilos, containing		0.703
		$9.200

The result of this experiment may be summed up as follows: —

	Per ton.
Gold by fire assay	$4.14
Gold extracted by amalgamation	3.53

or 85.2 per cent is saved by amalgamation.

The poverty of the iron pyrites concentrations found by us corroborates the conclusions arrived at by Professor Hitchcock, who says that he has universally found the gold in these mines to be in the quartz, and not intimately associated with the pyrites, as it is in some other localities.

II. The second lot of ore was taken from the same heap as the last, but at a different time. The lot weighed $403\frac{6}{100}$ kilos (888 pounds),

and assayed $4.14 per ton. When cleaned up, the different parts yielded gold as follows: —

Battery amalgam	$1.220
1st plate	.430
2d plate	.063
3d plate	.041
4th plate	.028
5th plate	.020
Mercury trap	.020
Total yield	$1.822

or $4.10 per ton.

According to the above assays the lot yielded to fire assay $4.14, to amalgamation $4.10 per ton, or 99 per cent of the gold was saved. This, of course, we cannot claim to have done; we can only say that the method of valuing by fire assay is not fine enough to give the cents exactly on such low-grade ore.

III. The third lot of ore was from Nova Scotia, and was composed of bluish-white quartz and blue slate. It contained a very little pyrites, arsenical pyrites, and galena. The gold sights, or visible lumps of gold, had all been picked out of this lot of ore; and when it was crushed in a Blake's crusher to one cubic inch in size, it showed no gold. These sights, I should judge, may have amounted to as much as $5 or $6 for the lots Nos. III. and IV. inclusive.

This lot, No. III., weighed 639.87 kilos (1407.7 pounds). No satisfactory valuation could be obtained from it, as the gold proved to be in such coarse condition. A sample of 48.45 kilos (106.6 pounds), when crushed and passed through a sieve having twelve holes to the linear inch, yielded: —

	Per ton.
Gold pellets on sieve	$7.10
Siftings, by fire assay	7.23
Total value	$14.33

After the ore was stamped and the mill cleaned up, the following figures were obtained from the different products.

639.87 kilos of ore containing gold		$10.0861
yielded products as follows:		
Gold immediately available.		
Battery amalgam	$9.1324	
1st and 2d plates amalgam, together	.1389	
3d plate amalgam	.0083	
4th plate "	.0188	
5th plate "	.0048	
Mercury trap	.0134	
	9.3166	

Gold recoverable from pyrites.

Pyrites concentrations 9.9 kilos	$0.1124	
Battery residue 7.05 kilos	0.0481	
		$0.1605
Gold lost in tailings, both the weight and the contents obtained by difference, weight = 622.92 kilos	0.6090	
		$10.0861

The amalgam from the battery was in large, coarse nuggets, attached together by liquid mercury. Scarcely any of this gold appeared to have made its way through the sieves. A very different result is shown in both the first and second lots of ore, where the gold was evidently fine, and therefore passed through quite freely, and more than one third was caught on the plates.

It should be stated here that the lot marked No. II. was run after that marked No. III. By comparing the yields of the plates of No. I., No. III., and No. II., it will be readily seen how perfectly we have overcome the overlapping error.

IV. A second portion of the above lot was stamped without the use of amalgam or amalgamated plates. This lot weighed 631.8 kilos (1390 pounds). When the battery residue was panned out, it yielded nuggets of gold valued at $8.24, or $11.85 per ton. The yields, therefore, by the above tests were: by fire assay, of doubtful accuracy, $14.24; by stamping with amalgamation, $13.24; by stamping alone through $\frac{1}{50}$-inch holes, $11.85.

It may not be amiss to sum up the principal precautions considered necessary by mill men, and confirmed by our experience.

The amalgam on the plates should not be allowed to get too hard or too soft. If too hard, it may fail to catch the gold; if too soft, mercury will flour at the lower end of the plates.

A quantity of mercury, varying from 1 to $1\frac{1}{2}$ ounces, should be fed to the stamps for every ounce of gold contained in the ore under treatment. This mercury should be fed a little at a time every half-hour. If the plates are inclined to stain, a lump of cyanide of potassium held a moment on the spot will remove the yellow stain. Too free use of the cyanide will cause the amalgam to soften too much on the plates, and cause a loss at the lower end.

Keith says, that if an ore contains ferrous or cupric sulphate (blue or green vitriol), as a result of oxidation of pyrites, and giving rise to the yellow stain on the plates, a little lime should be added along with the ore. This will precipitate the metals, forming harmless gypsum with the liberated sulphuric acid.

The use of oil about the mill should be restricted as much as possible, as this, more than anything else, causes the yellow stain to come. If the cams are oiled with an oily rag on a stick every half-hour, the excess and dripping may be largely prevented. Molasses is sometimes used to lubricate the cams, but it is a poor lubricant. It does no harm to the amalgam. The cams should be wiped clean every day.

Copper plates in the battery we are inclined to recommend strongly, although we have not used them ourselves, owing to the difficulty of making a quantitative experiment with them.

The development of this method of testing gold ores is largely due to the energy and zeal of the several assistants in the Mining Laboratory during the eight years 1872 to 1880; namely, Messrs. William Foster, E. Faunce, B. P. Tilden, and R. W. Lodge, who, together with the students of the successive classes, spared no pains or trouble to make the laboratory methods a success.

THE FISHERY QUESTION.

PART I. — THE NORTH AMERICAN FISHERIES, TO THE DISSOLUTION OF THE TREATY OF WASHINGTON.

An Abstract prepared as a Class Exercise in International Law, Fourth Year, Course IX., *by* JOHN W. LINZEE.[1]

THE fisheries of British North America have been a subject of international controversy from the commencement of the eighteenth century. Among European powers, France first availed herself of the riches to be found in the waters which washed the eastern shores of her possessions on the North American continent. France's ambition received a great check in 1745 from the conquest of Louisburg by troops composed mainly of Massachusetts men. But by the Treaty of Aix-la-Chapelle, in 1748, this fortress on Cape Breton was restored to France. War again broke out in 1755, and Louisburg was again besieged by an army, under Lord Amherst; the fortress was conquered, but the success was due in large measure to the fact that nearly one third of the effective men of Massachusetts were engaged in this expedition. By the Treaty of Utrecht, in 1713, France had given up Newfoundland and Nova Scotia. By the Treaty of Paris, in 1763, she gave up all her possessions on the St. Lawrence and by the sea, retaining only St. Pierre and Miquelon. To these islets she has clung with great pertinacity. The privileges she obtained by the Treaty of Utrecht, of participating in the fisheries of Newfoundland, and of frequenting a limited range of coast for the purpose of prosecuting these fisheries, remain in force to the present day, with few modifications.

No longer disturbed by the French fisherman, the colonists of New England prosecuted the fisheries with vigor and energy, but the industry was destined to receive a fatal blow from the home government. Parliament enforced the Navigation Laws, which effectually checked the export trade. The West India products were made dutiable in colonial ports, and the French again obtained virtual control of the fisheries. But by evasions of the law, Massachusetts merchants were able, notwithstanding Parliamentary action, to keep the industry alive. The course of legislation from the accession of

[1] For list of authorities consulted, see page 60.

the Stuarts down to the Revolution was directed towards restraining and breaking down the commerce of the Colonies. Duties were imposed on rum, molasses, and sugar imported into the Colonies from West India islands other than British. This act was designed to destroy the colonial trade with the French, Dutch, and Spanish islands, whereby the products of the islands were exchanged for fish. In 1775 the final blow came. Parliament determined to starve the colonists into submission. A bill was agreed to, to restrain the trade and commerce of the New England Provinces to England, Ireland, and the British islands in the West Indies, and to prevent any fisheries on the Banks of Newfoundland. Furthermore, encouragement should be given the fisheries of Great Britain and Ireland at America's expense. This aroused the colonists, and thus we see how large a place in their estimation the fisheries occupied, and how the latter figured among the causes which led to the Revolution.

The treaty of September 3, 1783, by which our independence was acknowledged, conceded to the people of the United States "the liberty to enjoy unmolested the right to take fish of every kind on the Grand Bank and on all the other Banks of Newfoundland, also in the Gulf of St. Lawrence, and at all other places in the sea where the inhabitants of both countries used at any time to fish heretofore; and also that the inhabitants of the United States shall have liberty to take fish of every kind on such part of the coast of Newfoundland as British fishermen shall use (but not to dry or cure the same on that island); and also on the coasts, bays, and creeks, and all other of His Majesty's dominions in America; and that the American fishermen shall have liberty to dry and cure fish in any of the unsettled bays, harbors, and creeks of Nova Scotia, Magdalen Islands, and Labrador, so long as the same shall remain unsettled; but so soon as the same, or either of them, shall be settled, it shall not be lawful for the said fishermen to dry or cure fish at such settlement without a previous agreement for that purpose with the inhabitants, proprietors, or possessors of the ground."

Between the signing of this treaty and the war of 1812, the British population along the shores of New Brunswick and Nova Scotia increased, and their fishing interests, enjoyed in common with the Americans, also greatly increased. Great Britain considered that, in accordance with the rules of international law, the liberty to fish granted by the treaty of 1783 naturally terminated by the war, and refused to grant Americans, gratuitously, the privilege they formerly enjoyed, and at the same time declined to consider the claim set up

by the United States government of "an immemorial and prospective right to the fisheries." No understanding was reached during the negotiations which ended in the Treaty of Ghent, in 1814, because of the untenable demands of the American Commissioners; and the officers of the English fleet in British waters were ordered not to interfere with American fishermen on the Banks of Newfoundland, in the Gulf of St. Lawrence, or on the high seas, but to exclude them from the harbors, bays, and creeks of all his Majesty's possessions. Some Americans who trespassed in British waters were seized, and the United States was finally forced to settle amicably a question which might at any moment lead to difficulties between the two countries. The result was a Convention between England and the United States, in which the rights of the two nations were clearly defined. These were, that the United States should have forever, in common with British subjects, the right to take and cure fish on certain parts of Newfoundland and Labrador, and on the coast of the Magdalen Islands, under a few restrictions respecting which no serious differences had arisen. The United States renounced forever the liberty formerly enjoyed or claimed by her inhabitants to take, dry, or cure fish on or within three marine miles of any of the coasts, bays, creeks, or harbors of British America, not included within the limits before mentioned, and the whole controversy in past years between England (representing the Dominion of Canada and Newfoundland) and the United States has been on the true effect of the renunciation, on the part of the latter, of this liberty. To the above, conditions were added, that American fishermen shall be permitted to enter such bays, etc., for the purpose of shelter and of repairing damages therein, of purchasing wood and of obtaining water, and for no other purpose whatever. The proviso as at first drafted contained, in addition to the privileges of obtaining shelter, wood, and water, the words "and bait." "This the American Commissioners consented to omit, in order to obtain as great an area for in-shore fishing as possible, thus sacrificing what has proved of greater importance." The treaty was made especially with reference to cod-fishing. It was concluded in the year 1818. American fishermen frequented the Grand Banks, and entered the bays and harbors of Newfoundland for repairs and bait, and questions have arisen as to the value of these privileges within her territorial limits. Other fishing grounds are the Bay of Chaleur, the coast of Cape Breton and of Prince Edward Island, and the Bay of Fundy; the last being, with the Gulf of St. Lawrence, the fishing ground so much valued by the fishermen of New England.

"Trouble soon grew out of the different interpretations of the treaty of 1818. American vessels were seized while engaged in fishing in the Bay of Fundy when more than three marine miles from shore. The United States government understood the phrase 'three marine miles from the coast' to mean from the coast following all sinuosities. But the English government claimed that it was from a line drawn from headland to headland."[1] The latter view, as advocated by most European authorities on international law, was unpalatable to us, since it shut Americans out from the Bays of Chaleur and Fundy and the Gulf of St. Lawrence, where the most important fishing exists. The well known authorities, Wheaton and Chancellor Kent, do not support the contention of the United States.

The American view was first advanced in 1824, when the United States complained of interference with their fishing rights. The seizure of vessels continued until, on the 10th of March, 1845, Lord Aberdeen announced to Mr. Everett, who was our Envoy to the Court of St. James, that, while the British government did not admit the American construction or abandon its own, yet, out of considerations of courtesy, it would grant to American fishermen the right to fish in the Bay of Fundy "outside of three marine miles." This Mr. Everett refused to accept, as it would place his government in a false position to take as a mere favor that for which they had so long contended as due them from the Convention.

For more than six years our diplomatic correspondence does not mention the fisheries. But between the years 1847 and 1851 overtures were made to the United States for a free interchange of natural products "of the British Colonies and the United States by treaty stipulation or legislation." Canada passed an act having this object in view, in 1847, to become operative when the United States should adopt a similar measure. But Congress refused to pass such a law, although persistently urged at three successive sessions. These propositions were closely followed by others from the British Minister at Washington for reciprocal trade, either through negotiations or mutual legislation. The President in 1851 informed Congress of the terms offered by her Britannic Majesty's government, which were, if the United States would admit "all fish, either cured or fresh, imported from the British North American possessions in vessels of any nation or description, free of duty, and upon terms in all respects of equality with fish imported by citizens of the United States," her Majesty's government would "throw open to the fishermen of the United States

[1] Elliott, p. 61.

the fisheries in the waters of the British North American Colonies, with permission to those fishermen to land on the coasts of those Colonies for the purpose of drying their nets and curing their fish, provided that, in so doing, they do not interfere with the owners of private property or with the operations of British fishermen." Meanwhile the Provinces had sent several fast-sailing vessels to protect the fisheries, while her Majesty's ministers promised a small naval force. It seemed from the above proposals and display that England intended to compel the United States to legislate under duress. To this our country was not likely to submit. Besides, the treaty was now thirty years old, and it recognized clearly the right of Americans to fish at a distance of three miles from any shore. Mr. Rusk argued that the object of the naval force was to bring about a reciprocity treaty, and that the domineering spirit of England ought to be met promptly. His resolution passed the Senate on the 23d of July, and a frigate was sent to protect American fishermen under the Convention of 1818.

In 1852, a commission sat in London to settle various claims, among which was one for indemnity for the seizure of the "Washington" in the Bay of Fundy. The commissioners disagreed, but the umpire, Mr. Joshua Bates, a member of the banking-house of Baring Brothers, decided that, since the Bay of Fundy was bounded by American territory at its mouth, it was not a British bay, within the meaning of the treaty, and that it was open to the American fishermen. This was an important gain for us.

"The Canadian fishermen found it difficult to compete against the American system of bounties, and the right to a free participation in the American market became an object of prime importance. Modifications in the United States revenue laws were opposed, on the ground that Canadian fish already monopolized the export trade," but in January, 1853, the United States consented to negotiate on the subject of their commercial relations with the British Empire; and Canadians were anxious that these deliberations should secure more extended markets for the productions of British America.

The negotiations resulted in the Reciprocity Treaty of 1854, drawn up at Washington by Lord Elgin and Secretary Marcy. By this treaty American fishermen gained fishing rights analogous to those they enjoyed under the treaty of 1783, while the Canadians obtained a market for their natural products free of duty. United States fishermen could fish on Canadian coasts without any restrictions as to distance; also certain natural products of the two countries, like fish, coal, meal, lumber, and salt, were allowed to enter into each free of

duty. This treaty seems to have been of benefit to both countries. It settled an ever present cause of irritation, and opened a large and increasing market for the export trade of British North America, while Americans prosecuted one of their great industries to great advantage. From an English point of view, this treaty was considered to have given the United States additional buyers for their products and manufactures. Besides, the maritime Provinces considered the concessions made to them inadequate compensation for the fisheries of British North America; for the Americans, by their greater enterprise and the superiority of their vessels, practically beat the British fishermen in their own waters, and derived advantages beyond any granted by the United States. Again, from the national point of view of an Englishman, this treaty had its dangers, in enticing thousands of enterprising youths of the Provinces into the fishing fleet of New England, and in making the commerce of the maritime Provinces largely dependent on the United States. In those days the Provinces were isolated from one another, and a political union between them seemed still far off. While the treaty lasted, the balance of trade with respect to manufactured goods amounted to $18,000,000 in favor of the United States.

From the standpoint of the United States, American fishermen were not satisfied with thus contributing towards building up the business of their competitors at the expense of their own interests; for it was asserted that the Canadian fishery interests now had a period of unexampled prosperity. It soon became evident that the loss of revenue from the remission of duty on Canadian importations far exceeded the value of the fishing rights conceded to American fishermen. It was contended that the Canadian fishermen, by reason of their proximity to the fishing ground and the cheapness of labor and material for building boats, were enabled to compete with the American fishermen to such an extent as to render their business unprofitable. This treaty terminated in March, 1865, in pursuance of notice given by the United States one year before. The action of the Washington government was hastened by the desire that generally prevailed in the United States to punish the Provinces for the sympathy the majority of them were believed to have extended to the South during the War of Secession.

The Convention of 1818 was again in force, but the British government did not insist on its construction of that treaty. The Canadian government now began to issue licenses permitting American fishermen to use the in-shore waters. But the importance of the in-shore

fishing to us had so decreased, that, after a trial of three years, it was announced that licenses would be stopped, the plan proving a failure. At about this period, 1868, several Provinces were consolidated into the Dominion of Canada, in consequence of which the Canadian Parliament acquired jurisdiction over the sea-coast fisheries. An act was passed by this Parliament in 1868, the principal provisions of which were : —

1. The government may grant licenses to fish within three miles of the coast. 2. Any one of a number of specified officers may go on board of any vessel within any harbor of Canada, or hovering within three marine miles of any of the coasts, bays, creeks, or harbors in Canada, and stay on board as long as she may remain within such place or distance. 3. If such vessel shall remain in such harbors for twenty-four hours after she has received notice to quit, the officer may bring her into port and search her cargo; also the master shall forfeit $400, if he answer wrongly questions put to him; also, if he be found fishing within such limits without a license, the vessel, stores, and cargo shall be forfeited.

The Treaty of Washington.

"On the 8th of January, 1870, the Governor of Canada issued an order, that henceforth all foreign fishermen shall be prevented from fishing in the Canadian waters." This was considered such a gross violation of the treaty then in force that the Secretary of State requested its modification from the British Minister. These negotiations resulted in the Treaty of Washington, in 1871. This treaty revived the reciprocity treaty of 1854, but British fishermen were allowed to fish in American waters down to the thirty-ninth parallel, and it was stipulated that "fish oil and fish of all kinds being the produce of the fisheries of the United States, or of the Dominion of Canada, or of Prince Edward Island, shall be admitted into each country, respectively, free of duty." "During the negotiations that led to the Treaty of Washington, the United States offered one million of dollars for the inshore fisheries in perpetuity, not because they were of that value, but in order to avoid future inconvenience and annoyance." The British government, on their side, asserted that the privileges granted to the citizens of the United States were of greater value than those accorded to the citizens of Great Britain; hence it was provided in the treaty that a Commission should be appointed to determine the value of these additional privileges. The treaty stated that one of the Com-

missioners should be appointed by the President of the United States, one by her Britannic Majesty, and the third conjointly, and in case the third Commissioner should not have been named within a period of three months from the date when the treaty took effect, then the third Commissioner should be named by the representative at London of his Majesty the Emperor of Austria and King of Hungary. This latter clause showed carelessness on the part of the United States, for only a few years previously a member of the house of Habsburg had lost his life in Mexico through the support given the government of President Juarez by the United States. Great Britain recognized this mistake, and was swift to take advantage of it. "She determined from the first that no third Commissioner should be chosen within the three months, and so resorted to all plausible means to delay the negotiations," and she succeeded. For at the appointed time the Austrian Minister appointed M. Delfosse, the Belgian Minister, who of course was well inclined to England, since Belgium owed its political existence to Great Britain. The Commissioners met at Halifax, and the United States was adjudged to pay $5,500,000 for the use of the fishing privileges for twelve years.

There were two peculiar features about this award, viz.: — 1. That the award was made by two Commissioners, when it should have been unanimous. 2. That the amount was exorbitant. "The customs receipts for the four full years from 1873 to 1877 showed that the United States had remitted duties on fish amounting to three hundred and fifty thousand dollars a year, and when that was added to the award it was equivalent to almost ten million dollars for the use of the in-shore fisheries for twelve years, while they were not worth more than twenty-five thousand dollars a year." Notwithstanding these facts, the Senate Committee on Foreign Relations recommended the payment of the award, if Great Britain was willing to accept it. In the interval between the signing of the treaty and the payment of the award, new methods of catching mackerel had still further reduced the value to us of the Canadian in-shore fisheries. Consequently, it is not to be wondered at that the treaty gradually became unpalatable to the United States, so that, in pursuance of instructions from Congress, the President gave the required notice of the desire of the United States to terminate the Fishery Articles of the Treaty of Washington, which subsequently came to an end on the 1st of July, 1885.

The Convention of 1818 should have once more governed the relations of the two countries, but the termination of the treaty fell in the midst of the fishing season, so that the treaty remained in force

during the remainder of the season, on the understanding that the President should recommend to Congress, at its next session, a joint Commission by the two governments.

The following diagram gives an idea of the rights and liberties to which citizens of the United States are entitled in the northeastern fisheries under the

TREATY OF 1818.[1]

- **Rights of American Fishermen.**
  - **Of Fishing.**
    - In the deep sea.
    - **In Territorial Waters.**
      1. On the southern coast of Newfoundland, from Cape Ray to the Rameau Islands.
      2. On the western and northern coasts of Newfoundland, from Cape Ray to the Quirpon Islands.
      3. On the southern shores of the Magdalen Islands.
      4. On the coast, bays, harbors, and creeks, from Mount Joly on the southern coast of Labrador to and through the Strait of Belleisle, and thence northwardly indefinitely along the coast.
  - **Other than Fishing.**
    1. To dry and cure fish in any of the unsettled bays, harbors, and creeks of the southern part of the coast of Newfoundland described, and of the coast of Labrador, while unsettled, after which the consent of the inhabitants, proprietors, or possessors of the ground must be obtained.
    2. To enter all bays and harbors for the purpose of shelter, repairing damages, and procuring wood and water.
- **Rights renounced.**
  - Any liberty heretofore enjoyed or claimed to take, dry, or cure fish on or within three marine miles of any of the coasts, bays, creeks, or harbors not included in the above mentioned limits.
- **Rights claimed but denied by Canada.**
  1. To purchase bait and other supplies.
  2. To land and trans-ship fish.
  3. To enter bays and harbors to prepare fish, and to clean and pack fish.
  4. The commercial privileges of traders.
  5. To navigate the Gut of Canso.

REFERENCES.

C. B. Elliott, The United States and Northeastern Fisheries. Univ. of Minnesota, 1887.
The Westminster Review. Vol. CXXIX. pp. 82–100.
Senate Committee on Foreign Relations. Edmunds's Report and Appendices, 1887.
Wharton, Digest of International Law. Vols. II. and III.

[1] Elliott, p. 104.

SOME POINTS IN THE DETERMINATION OF SILICA IN SILICATES BY FUSION WITH ALKALINE CARBONATES.

BY JAMES P. GILBERT, S. B.

THE usual method of determining silica in silicates — that of fusion with the alkaline carbonates, decomposition with hydrochloric acid, and subsequent evaporation to dryness — does not always give satisfactory results. This method is universally described in the text-books as being accurate, with the occasional caution that the filtrate should also be examined for any silica which may not have been rendered insoluble by evaporation to dryness. But one looks in vain for any intimation of what may be the amount of the error, in the determination of silica as usually carried out, if one neglects to examine the filtrate. There is no doubt that many chemists have had trouble with this method, and some have given it up, preferring to volatilize the silica with hydrofluoric and sulphuric acids, and, after a careful analysis of the residue, to calculate the silica by difference. A recent writer[1] makes the statement that he has never been able to obtain more than 97.5 per cent of the total silica in highly siliceous bodies by the fusion method. The following work was undertaken in the hope of discovering some of the sources of error in the fusion process.

The influence of the temperature at which the silica is dehydrated was first investigated. Most authorities say that evaporation on the water bath to complete dryness, or until no more hydrochloric acid is given off, is sufficient to dehydrate the silica, but a few recommend subsequent heating in an air-chamber to a temperature of 110° C. A higher temperature than 110° C. is said by Fresenius to be inadmissible, since there is liability of the silica recombining with the bases present to form silicates partially decomposable with hydrochloric acid.

To test the influence of temperature on the amount of silica obtained, the following determinations of silica were made in a blast-furnace slag containing about 46 per cent of lime, 10 per cent of alumina, and less than one per cent of magnesia. The silica was dehydrated at various

[1] George Craig: Chem. News, Vol. LX. No. 1563.

temperatures, but in all other respects the process was carried out exactly as Fresenius directs. What is generally called silica, that is, the mass insoluble in hot hydrochloric acid after evaporation to dryness, is given in Column I. of the following table. This was treated with hydrofluoric acid and the weight of the residue is given in Column II. In the filtrate from the silica the alumina was precipitated by ammonia, dried, ignited, and then fused with potassium bisulphate. The residue left on treating the fused mass with water, (and correcting for the impurities of the bisulphate used,) is given in Column III. The total silica in Column IV. is calculated by subtracting the weight of the residue left after treatment with hydrofluoric acid from the weight of the silica as given in Column I., and adding that found with the alumina in Column III.

TABLE I.—ANALYSES OF BLAST-FURNACE SLAG (CONTAINING 46 PER CENT LIME) BY FUSION WITH ALKALINE CARBONATES.

	I. Residue insoluble in hydrochloric acid after evaporation to dryness.	II. Weight of residue obtained from treating Column I. with hydrofluoric acid.	III. Weight of Silica found in Alumina.	IV. Total Silica.		I. Residue insoluble in hydrochloric acid after evaporation to dryness.	II. Weight of residue obtained from treating Column I. with hydrofluoric acid.	III. Weight of Silica found in Alumina.	IV. Total Silica.
	Per cent.	Grams.	Grams.	Per cent.		Per cent.	Grams.	Grams.	Per cent.
1	41.25	.0003	.0006	41.26	9	41.33	.0013	.0005	41.25
2	41.34	.0024	.0008	41.17	10	41.71	.0036	.0007	41.42
3	41.39	.0012	.0009	41.33	11	41.53	.0028	.0007	41.27
4	41.32	.0020	.0003	41.18	12	41.89	.0031	.0004	41.35
5	41.22	.0012	.0009	41.19	13	41.79	.0032	.0002	41.41
6	41.43	.0021	.0007	41.23	14	41.65	.0027	.0005	41.43
7	41.40	.0014	.0009	41.32	15	41.90	.0028	.0001	41.48
8	41.48	.0017	.0008	41.35					

Nos. 1 to 3 inclusive were dehydrated on the water bath.

Nos. 4 to 6 inclusive were dehydrated at 125° C.

Nos. 7 to 9 inclusive were dehydrated on iron plate over Bunsen burner.

Nos. 10 to 15 inclusive were dehydrated in air-chamber at 280° C.

All evaporations were made in porcelain.

In this series of results it will be seen that the silica was practically all rendered insoluble even at the temperature of the water bath, and that there was no gain in this respect in using a higher temperature. But the amount of foreign matter in the silica was, in general, perceptibly higher at the higher temperature of dehydration. This is probably due to the alumina being rendered partially insoluble in acid. From the fact that very little silica was found in the alumina, it would seem as if there were no tendency for the silica to recombine with the lime and alumina even at a temperature of 280° C. Nos. 13, 14, and 15 were digested, after dehydration, with hot acid for one hour, in the expectation of dissolving out all the alumina and other bases, but this treatment did not give smaller residues, after the volatilization of the silica with hydrofluoric acid, than in Nos. 10, 11, and 12, which were treated only thirty minutes with acid.

The general uniformity of the results in this series suggested the possible influence of the calcium chloride present in dehydrating the silica on evaporation to dryness. This led to the second point con-

TABLE II. — ANALYSES OF A BLAST-FURNACE SLAG (CONTAINING 35 PER CENT LIME AND 15 PER CENT MAGNESIA).

	I. Residue insoluble in hydrochloric acid after evaporation to dryness.	II. Weight of residue obtained from treating Column I. with hydrofluoric acid.	III. Weight of Silica found in Alumina.	IV. Total Silica.		I. Residue insoluble in hydrochloric acid after evaporation to dryness	II. Weight of residue obtained from treating Column I. with hydrofluoric acid.	III. Weight of Silica found in Alumina.	IV. Total Silica.
	Per cent.	Grams.	Grams.	Per cent.		Per cent.	Grams.	Grams.	Per cent.
1	33.65	.0032	.0032	33.61	7	33.49	.0032	.0011	33.24
2	32 90	.0014	.0025	33.18	8	33.85	.0045	.0012	33.27
3	33.46	.0013	.0013	33.29	9	33.90	.0042	.0012	33.30
4	33.71	.0027	.0004	33.40	10	33.65	.0062	.0062	33.62
5	33.42	.0021	.0008	33.24	11	33.83	.0046	.0045	33.80
6	33.75	.0031	.0004	33.36	12	33.95	.0088	.0050	33.60

Nos. 1 to 3 inclusive were dehydrated on the water bath.

Nos. 4 to 6 inclusive were dehydrated at 120° C.

Nos. 7 to 9 inclusive were dehydrated on iron plate, over Bunsen burner.

Nos. 10 to 12 inclusive were dehydrated at 280° C.

sidered, namely, the influence of the salts present on the determination of silica. It is not unreasonable to suppose that some salts, such as calcium chloride, may have a beneficial influence, while others, as, for example, magnesium chloride, which is decomposed when its solution is evaporated, may vitiate the silica determination by forming a silicate which will be subsequently decomposed by hydrochloric acid with solution of the silica. To test the effect of magnesium chloride determinations of silica were made in a slag containing about 35 per cent of lime, 15 per cent of magnesia, and 15 per cent of alumina. (See Table II.)

This series differs from the first mainly in the large amount of impurity in the silica and the large amount of silica in the alumina when the dehydration is effected at a temperature of 280° C. The best results were obtained at a temperature of 120° C. The increase of silica in the alumina as the temperature is increased would seem to be due to the magnesia, for the conditions were, in all other respects, the same as in the analyses of the other slag. The above results indicate that there is no danger of the silica combining with the magnesia at 120° C., and that at this temperature the silica is almost completely dehydrated, the calcium chloride probably assisting in the dehydration.

A series of analyses was next made on orthoclase, practically free from lime and magnesia.

TABLE III. — ANALYSES OF A SAMPLE OF ORTHOCLASE.

	I. Residue insoluble in hydrochloric acid after evaporation to dryness.	II. Weight of residue obtained from treating Column I. with hydrofluoric acid.	III. Weight of Silica found in Alumina.	IV. Total Silica.		I. Residue insoluble in hydrochloric acid after evaporation to dryness.	II. Weight of residue obtained from treating Column I. with hydrofluoric acid.	III. Weight of Silica found in Alumina.	IV. Total Silica.
	Per cent.	Grams.	Grams.	Per cent.		Per cent.	Grams.	Grams.	Per cent.
1	64.80	.0018	.0004	64.52	5	64.98	.0050	.0019	64.45
2	64.13	.0018	.0030	64.30	6	64.62	.0035	.0020	64.36
3	64.03	.0026	.0035	64.20	7	64.83	.0068	.0030	64.45
4	64.35	.0020	.0030	64.52	8	64.97	.0083	.0039	64.35

Nos. 1 and 2 were dehydrated on the water bath.
Nos. 3 and 4 were dehydrated at 120° C.
Nos. 5 and 6 were dehydrated on iron plate over Bunsen burner.
Nos. 7 and 8 were dehydrated at 280° C.

This series differs from the previous one in that the higher temperature is not accompanied with an increased amount of silica in the filtrate. This would seem to be a confirmation of the idea that there was a recombination of the silica and the magnesia at the temperature of 280° C. in the magnesia slag; and the fact that the amounts of silica found in the alumina are (with one exception) uniformly higher than those in the lime slag indicates, I think, the beneficial effect of the calcium chloride in the dehydration of the silica.

The third point considered was the influence of temperature on the dehydration of the silica when no bases other than the alkalies were present. From the last three series of analyses it would seem that some silica always fails to be rendered insoluble by heat alone, so that, if a definite amount of pure silica were taken and subjected to alternate fusions and dehydrations, we should expect that the amount of silica obtained would diminish at each successive treatment. To ascertain if this were so, two determinations of silica were made in the lime slag, and the silica thus obtained repeatedly treated by fusion with alkaline carbonates in the usual way. The per cent of silica recovered in each case is given below. The silica obtained from the slag by the first fusion and dehydration is taken as 100 per cent.

	I. Per cent.	II. Per cent.	
1.	42.02	41.81	Silica in slag obtained by heating to 280° C.
2.	97.24	97.79	Percentage of the above obtained in four successive fusions by heating to 120° C.
3.	96.04	96.70	
4.	95.17	95.96	
5.	94.19	95.45	

The large difference between the results of the first and second fusions is probably due to impurities in the silica, which was heated to 280° C.; but the variations in the other cases can only be due to loss of silica by incomplete dehydration. Still, these are better results than Craig obtained, who does not, however, mention the temperature he used in dehydrating the silica.

The fourth point considered was the possibility of obtaining the silica in a purer state, that is to say, to decrease the amount of the residue left after treatment with hydrofluoric acid. This residue may be due to imperfect washing, or to the fact that alumina has been rendered insoluble in hydrochloric acid by prolonged heating to a high temperature. The higher residues obtained in the cases in which the silica was heated to 280° C. point to the latter possibility. But it is not improbable, as will

be mentioned later on, that under certain conditions the silica may enclose alkaline salts so that it is impossible to remove them completely by washing.[1]

In an interesting article by Lindo,[2] on the analysis of glass, I met the recommendation that the watery solution of the fusion be diluted to a very large bulk, so that on acidifying with hydrochloric acid there shall be no precipitation of silica. In this way he obtained, on evaporation, what he called "vitreous silica," in distinction from the ordinary "amorphous silica." This vitreous silica, he says, is so easily washed that time is gained in the analysis to compensate for that lost in the evaporation of the solution. Lindo takes it for granted that one cannot get all the silica by the ordinary process of dehydration, and that the last traces of it cannot be got out of the filtrate unless there is sufficient iron oxide or alumina present to effect its complete precipitation. In the analysis of glass, he added a known amount of ferric chloride to the filtrate from the alumina, and by precipitating this iron with ammonia the last traces were obtained.

The following analyses of glass were made according to his directions. The powdered glass, about one gram, was fused with five grams of sodium and potassium carbonates, and the mass treated with about four hundred cubic centimeters of boiling water until it was thoroughly disintegrated. On acidifying with hydrochloric acid, a clear solution

TABLE IV. — DETERMINATIONS OF SILICA IN GLASS. (LINDO'S METHOD.)

	I. Silica obtained after two fusions.	II. Residue from Column I. with hydrofluoric acid.	III. Silica obtained from the filtrates.	IV. Total Silica.
	Per cent.	Grams.	Grams.	Per cent.
1	73.03	.0003	.0058	73.58
2	71.81	.0008	.0125	73.06
3	72.50	.0004	.0084	73.22
4	71.96	.0000	.0051	71.43
5	71.25	.0007	.0060	71.70

[1] In this connection it is interesting to note that all the residues left on treatment with hydrofluoric acid, in the two slags analyzed, contained manganese, which may point to an insoluble compound of manganese with the alkaline salts.

[2] Chemical News, Vol. LX. No. 1546.

was obtained. This was evaporated to dryness on a water bath, heated to 125° C., and, as recommended by Lindo, the silica thus obtained again fused and treated as before. This silica obtained from the second fusion was weighed, and then treated with hydrofluoric acid. The two filtrates were combined and evaporated to dryness, heated to 125° C. for one hour, and the residue, insoluble in hydrochloric acid and water, filtered off; this is given in the third column. The first three analyses are of German "half-white" glass; the last two, of Bohemian white glass.

In this case it is seen that a considerable portion of the silica fails to be dehydrated by one evaporation and heating to 125° C. The silica obtained in this way is very compact, and the washing, as claimed by Lindo, is very easily done. The purity of the silica thus obtained (shown by the small residue left on treatment with hydrofluoric acid) is doubtless in part due to the facility with which the silica is washed; for it is conceivable that, when the silica is separated from a concentrated solution of alkaline salts, it may enclose particles of the liquid which may not be easily washed out. But this high purity, as compared with the silica obtained from the slags and the feldspar, may be due to the absence of any large amount of alumina in the glass.

To see what would be the character of the silica obtained from the first slag by large dilution of the solution of the fused mass before acidifying, the following determinations were made.

TABLE V. — AMOUNT OF FOREIGN MATTER IN SILICA OBTAINED FROM LIME SLAG. (LINDO'S METHOD.)

	I. Weight of Silica obtained from Slag.	II. Residue from Column I. with hydrofluoric acid.	
	Grams.	Grams.	
1.	.2755	.0008	Silica obtained by evaporation to dryness on water bath.
2.	.2610	.0010	
3.	.2871	.0008	Silica obtained by evaporation to dryness and heating to 125° C.
4.	.2683	.0012	
5.	.2506	.0036	Silica obtained by evaporation to dryness and heating to 280° C.
6.	.3113	.0043	

These figures would seem to justify the inference that in the presence of considerable alumina it is not possible, even by large dilution, to get as pure silica as is easily obtained when only salts of the alkalies or alkaline earths are present.

The foregoing determinations confirm the statement that the ordinary process of fusion with alkaline carbonates and evaporation to dryness

cannot always be relied on to render all the silica insoluble. No experiments were made to determine the effect of *repeated* evaporations to dryness with hydrochloric acid.

When the evaporation is carried out in the presence of free sulphuric acid the results are more satisfactory, but, as Craig says, the amount of alkaline sulphates introduced seriously interferes with the determination of the bases present.

A comparison of results obtained from a sample of quartz by evaporation with hydrochloric and sulphuric acids is given below.

I. Silica by evaporation to dryness with hydrochloric acid and heating to 120°.	II. Silica by evaporation to dryness with sulphuric acid.
Per cent.	Per cent.
98.95	99.43
98.60	99.67
98.79	99.51
	99.70

In these determinations I followed Lindo's recommendation of diluting largely before acidifying, and the residue left, on treatment with hydrofluoric acid, was very small. The first two determinations by sulphuric acid were done by decomposing the dilute watery solution of the fusion with hydrochloric acid, evaporating to dryness, and then adding strong sulphuric acid in excess and heating on an iron plate until copious fumes of sulphuric acid were given off for several minutes. The silica was in appearance the same as obtained by Lindo's method with the aid of hydrochloric acid only. But in the last two the watery solution of the fusion was decomposed directly by sulphuric acid in considerable excess, and then evaporated as before. The silica obtained in this way was very bulky and gelatinous.

These results seem to justify the recommendation that has been made; namely, that in the analysis of silicates the silica is best determined by dehydration with sulphuric acid (in cases where it is not inadmissible by the presence of lime, barium, lead, etc.), and that the bases should be determined, after the decomposition of the silicate, by hydrofluoric acid.

MASS. INSTITUTE OF TECHNOLOGY,
January, 1890.

THE DATA OF FILTRATION. — I. *SOME RECENT EXPERIMENTS ON THE REMOVAL OF BACTERIA FROM DRINKING WATER BY CONTINUOUS FILTRATION THROUGH SAND.*

BY WILLIAM T. SEDGWICK, ASSOCIATE PROFESSOR OF BIOLOGY.

FILTRATION on the large scale is gradually coming to be regarded by experts as the only adequate and practical safeguard against contamination, the only available remedy for pollution, of public water supplies. Most American cities have hitherto shrunk from the heavy pecuniary outlay involved in filtration, and have preferred to rely for protection simply upon the general good character of the water-shed from which their supply is taken. Experience has shown, however, that surface waters, no matter how carefully collected or stored, are apt to suffer more or less from the presence of various vegetable or animal growths, which, on decaying, support bacteria, and give rise, either directly or indirectly, to troublesome and disagreeable tastes, odors, or turbidities. Ground waters, though usually very pure when first drawn, may, if stored in open reservoirs, suffer still more severely from the algæ or other organisms which they readily support, — sometimes in such abundance as to render the water disgusting and totally unfit for drinking. Waters in this condition will sometimes recover, after a time, their original purity; but in order to make them fit for immediate use they must be filtered. Moreover, there is reason to believe that, with the increase of population, districts suitable for uncontaminated water-sheds, etc. must grow constantly more and more rare, until eventually no large city will have within reach enough of potable water to constitute, unfiltered, a pure supply. Already, indeed, the larger cities like New York and Boston are anxiously seeking to protect the purity of their respective water-sheds, always at large expense and often only after prolonged and uncertain litigation. At the same time, fresh and more numerous complaints of "fishy" or "cucumber" tastes in stored waters are constantly testifying to the difficulties involved in satisfying the inhabitants of a modern civilized city or town with water drawn directly from a reservoir teeming with organisms, dead or alive, and without any attempt at its purification.

In view of this condition of things, it is not unreasonable to suppose that purification of some sort will soon become a necessity in American water-works precisely as it has been found indispensable in the case of certain European cities, e. g. London, Berlin, and Zürich. The remedy applied in these cases is continuous filtration through sand, and it is the present opinion of experts that in filtration, either continuous or intermittent, a sufficient protection of water supplies will eventually be found. No apology need be made, therefore, for putting before American students of sanitary science some of the latest results of European experience.

The problems involved in filtration (aside from questions of cost, administration, etc.) are three-sided, viz.: (1) engineering, (2) chemical, and (3) biological. The chemical and biological data alone concern the actual purification of the water; the engineering data are more purely mechanical, and will be considered only incidentally. The present paper will deal almost exclusively with a single biological problem of fundamental importance in all filtration, — namely, *the possibility of the passage of bacteria* (*including pathogenic bacteria*) *through sand filters*, — and will be still further confined to a summary account of some recent and highly important experiments in this direction made by an eminent authority, Dr. Carl Fraenkel, upon the sand filters of Berlin, Germany.

The water supply of Berlin is in part derived from a very objectionable source, the river Spree, but is purified, before being delivered to the inhabitants, by filtration through sand. It must be understood, moreover, that these sand filters are run continuously; i. e. their surfaces are not allowed to get dry, and the flow through them is steady rather than irregular. They are therefore very unlike filters of similar material worked intermittently, — such, for example, as those which have been so successful in the Lawrence Experiment Station of the State Board of Health of Massachusetts, — and the Berlin sand filters are especially interesting as excellent examples of continuous filtration carefully studied from the biological standpoint. Sanitary engineers who desire to avail themselves of the experience of the engineers of the Berlin water-works should consult an important paper on "Water Supply, from the Hygienic and Technical Standpoint," by Piefke, engineer of the city water-works of Berlin. ("Aphorismen über Wasserversorgung, vom hygienisch-technischen Standpunkte aus bearbeitet." C. Piefke, *Zeitschrift für Hygiene*, VII., 1889, p. 115.) This paper is also a valuable biological contribution, and should be in the hands of every sanitary biologist.

The bacteriological supervision of the Berlin filters has apparently been very thorough, and has repeatedly shown so great a reduction of the numbers of bacteria in the effluent as compared with those in the unfiltered water, that the impression appears to have become general that no bacteria really pass *through* the best filters, those found in the effluent being accounted for by contamination from the air, or by errors in manipulation, experiment, etc.

The outbreak of a serious epidemic of typhoid fever in certain districts of Berlin between January and April, 1889, (some five hundred cases having been reported,) and the comparative localization of the fever in the eastern portion of the city, threw suspicion upon the water supply, and led to the inquiry, Are the sand filters a sufficient protection against the introduction of pathogenic germs from the polluted river into the service pipes, or may bacteria pass, alive and virulent, through the layers of sand?

The solution by actual experiment of this difficult, but highly important, problem was referred by Koch to his assistant, Dr. Carl Fraenkel, a biologist of the highest reputation. The work was carried on during the summer and fall of 1889, and, in a lecture before the German Society for Public Hygiene, Fraenkel has given a preliminary account of his results, which appears in the *Deutsche Medicinische Wochenschrift* for December 12, 1889. The complete account will appear hereafter, but the results already reached are important enough to receive immediate attention. (*Wird das Trinkwasser der Stadt Berlin durch die Sandfiltration mit Sicherheit von etwaigen Infectionsstoffen befreit?*—Deutsche Med. Woch., Dec. 12, 1889.)

By the cordial co-operation of the authorities of the city water-works, and especially of C. Piefke, the engineer in charge, (whose work is referred to above,) it became easy to construct filters imitating precisely those in actual use, and in general to carry on the experiments under the normal conditions. It was obviously out of the question to undertake any experiments with pathogenic germs upon the filters actually in use, and therefore one of the first steps was to construct small tanks on the same pattern. A barrel-shaped wooden tank, 2 meters high and 0.75 meter in average diameter, having at the bottom a sieve-like perforated support, was filled precisely like the large tanks in actual use; namely, with 150 mm. of stones of the size of a fist, 80 mm. of coarse gravel, 100 mm. of fine gravel, and 600 mm. of finer (*scharf*) sand. The surface was thus one meter below the top of the tank, and was provided with an overflow. Special means were provided for avoiding sudden changes in pressure, so that the flow was perfectly regular and under control.

It was considered safer to begin the experiments with a harmless bacterium, and accordingly the preliminary experiments were made with *Bacillus violaceus*. This species was chosen, not only because of the comparative ease with which it can be detected, but also because of its rarity, and of the fact that it might be supposed as likely as any to survive the passage through the sand. It was cultivated in a very weak solution (1 part of ordinary bouillon in 20 parts of distilled water) in order to avoid the objection which otherwise might have been raised, that the germs had found in the tank itself, thus fed, the means of continued existence, or even of multiplication, and so eventually had spread to the very bottom of the tank, and finally passed out. Small doses of this fluid, which had a faint bluish color, were added to the unfiltered water, from time to time, and usually at regular intervals of six hours. The supernatant water was then stirred up in order to secure an even distribution of the violet bacillus all over the top of the tank. Samples of the water standing on the surface of the sand, as well as of the effluent, were examined bacteriologically every day, and the results of a prolonged trial, lasting from June 1 to the end of July, went to establish the fact that, *contrary to the prevailing opinion, the Berlin continuous sand filters are by no means germ tight.* The least efficient periods, moreover, are those in which the filters are "young," i. e. are not yet covered on top with a layer of organic material accumulated from the water previously passed through (*Schmutzdecke, Deckhaut, Filz*), or, on the other hand, "old," i. e. so covered with organic matter "felted" together that water passes through only under the compulsion of a high pressure. It was observed, however, that after prolonged running the number passed out increased somewhat, even under no marked increase of pressure, and Fraenkel suggests that possibly some other cause than mere pressure is at work in such cases; such, for example, as the effect of the steady accumulation of food material within the tank, giving support finally to an undue number of bacteria in the lower layers.

In any case, it appears that the number of germs in the effluent is directly dependent on the number in the supernatant (unfiltered) water. Any change in the number of *B. violaceus* applied was soon followed by a corresponding change in the effluent. Moreover, the rate of flow seemed to be of the utmost significance. The filter which was run at the higher speed always showed the more bacteria, and, indeed, so uniformly, that Fraenkel declares the results proportional. Thus, with one filter running at 300 mm. speed and another at 100 mm., it appeared that three times as many blue colonies were contained in the effluent

of the former as in the effluent of the latter. He therefore lays down the rule, that *the qualitative efficiency of a continuous filter is inversely proportional to its quantitative efficiency.*

These preliminary experiments pointed clearly to the outcome of those upon pathogenic germs, although there was the possibility that these, being doubtless more delicate, might not survive in the (to them) unusual environment of a sand filter. In fact, it has been shown repeatedly, in laboratory experiments, that certain pathogenic germs speedily die out in water containing other germs. The temperature, also, was clearly against them, so that a hope might not unreasonably have been entertained that they would be killed in the filters. From the end of July to the middle of October Dr. Fraenkel experimented with the same filters as before, now using pathogenic germs. The results showed that *the germs of cholera and typhoid may also pass through the sand filters.*

The number of these germs in the effluent depends upon the number in the unfiltered water, and on the rapidity of filtration. The beginning and the end of the filtration period are especially dangerous times, because in the former case the filter has not attained its most effective condition, and in the latter the pressure, as well as perhaps the gradual charging of the whole filter (*Durchwachsen*) with live bacteria, tends to favor the discharge of the germs.

These results are directly opposed to the prevailing opinions concerning sand filters. There was, however, no good reason to doubt that the filters used were quite as effective as the actual large Berlin filters. The general belief that the Berlin continuous filters allow no germs to pass through them does not appear to have been well founded. It rested, for the most part, upon the observation that the number of germs discharged bore no apparent relation to the number applied. The former was fairly constant, the latter very variable. Hence it was inferred that the germs found in the effluent were due merely to contamination from the lower layers, or from the air. The filters themselves were regarded as "germ tight."

Fraenkel points out, however, that it is unfair, as is the custom, to compare the water of the river with that in the service pipes, both samples being taken on the same day, since the pipe water of any given day has not necessarily the slightest connection with the river water of the same day or hour. In the absence of experimental evidence it is impossible to say just how long is required for any particular portion of water to pass through the filters and reach a particular region of the city. But it is certain that the micro-organisms do not all pass on with the same velocity, nor do they keep pace with the

water in which they exist. Again, it appears that the very idea of considering the germs in the effluent as having come in part from the lower layers, which in turn were charged from above in an earlier period, is a partial and tacit admission that germs may pass through, — as it has been shown that they do in Piefke's experiments upon new or sterilized filters, — so that the period of complete exclusion is at the best but limited.

Lest any one should conclude from these experiments, that, because the filters are not absolutely germ tight, they are therefore practically worthless, Fraenkel strongly insists that such a conclusion would be very unjust and fallacious. The reduction in the number of germs by an effectively working and intelligently operated sand filter is in truth astonishing; but it is clear that any such system as is necessary for a large city requires the most skilful and intelligent supervision, if the results are to be of the best. Furthermore, since it appears from these experiments that the number of germs in the effluent depends directly upon the number applied, it becomes highly important to employ for filtration the best water available. It is not a matter of indifference whether the water to be filtered be good or bad. Only the best water is susceptible of the highest purification. The rate of filtration is also obviously extremely important, and requires constant attention. It may be urged that in these experiments the number of germs applied was very large, — much larger than would be likely to occur even in a badly polluted supply in actual service. This is certainly true, but does not forbid the possibility of such germs passing through, although it greatly reduces the probability. On the other hand, it must not be overlooked that the samples of effluent actually examined were only a very small portion of the entire effluent, so that there is a possibility of the escape from the filters of a much larger number than was found. Moreover, if it be allowed that the germs may multiply in the filter, or that they are hardy, — as increasing evidence seems to be indicating in the case of typhoid fever, — the way is at once open for the filters to become breeding places, as well as passages for germs.

The answer to the question whether or not the epidemic of typhoid fever, referred to at the outset, might possibly have come from germs which escaped detention by the sand filters, is obvious; whatever the probability, the possibility cannot be denied.

The foregoing study of the bacterial efficiency of continuous filtration of drinking water is, from the standpoint of public hygiene, of the utmost importance. For sewage disposal, however, continuous filtra-

tion fails utterly, since there is no free oxgyen in sewage, and hence no nitrification, or other purification, except the purely mechanical effect of the straining out of suspended matters, which leads to speedy stoppage of the filters. In drinking waters there is usually an abundance of free oxygen, so that continuous filtration might, theoretically, allow the complete nitrification of the suspended matters mechanically held back. That this does not take place is probably due partly to the fact that the arrival of fresh material for oxidation takes place more rapidly than its removal by nitrification, and partly because nitrification appears to require a more or less prolonged contact between bacteria and the substances to be oxidized. It appears, therefore, that in the case of drinking water rich in oxygen, as well as of sewage destitute of oxygen, the process of continuous filtration is effective chiefly in the removal of suspended matters, and of these the finest particles (bacteria) are imperfectly separated. Intermittent filtration, on the other hand, readily effects the nitrification of the organic matters in sewage, by allowing the entrance of oxygen into the sand between the flooding periods, and the purification of drinking water, by similar oxidation of the matters mechanically held back.

It is interesting to observe the striking effect of continuous filtration upon the bacteria in the water supplies of Berlin and Zürich. According to Piefke, in the paper referred to above, omitting certain extreme cases, it appears that, from July, 1885, to April, 1886, the average number of living bacteria in the unfiltered water of the river Spree was 3,609 per cubic centimeter. During the same period the effluent from the sand filters averaged only 63. Similarly the unfiltered water of Tegel Lake contained 505; the effluent, 51. In Zürich during 1886, the lake water drawn from a depth of 12 meters averaged 159. The filters were worked at a very rapid rate (7 m. per day), yet the average bacterial condition of the effluent was excellent, namely, 24 per cubic centimeter. In 1887, owing to an extension of the plant, the filters were run more slowly (at about 200 mm. per hour), and although the lake water showed a higher bacterial content (246), that of the effluent was lower than before (19). These figures show conclusively that, although far from perfect, the bacterial purification of drinking water by continuous filtration is still very great. If all the algæ, fungi, and animal forms, as well as the débris and other suspended matters, are also removed, as they appear to be, the final result of such filtration must certainly be pronounced very satisfactory.

THE LANGUAGE OF "THE LIFE OF THOMAS BECKET."

BY FRED P. EMERY, INSTRUCTOR IN ENGLISH.

A VERY popular species of composition, during the twelfth, thirteenth, and fourteenth centuries, was the collection of fabulous stories known as the *Legenda Aurea*, stories of the lives of the saints and martyrs, who performed most incomprehensible deeds of charity and devotion, who endured torture, not because they must, but because it served to manifest their goodness, and who at last died that they might be the shining lights of the little candles that enlumine this wicked world.

To say who was the favorite saint of the Middle Ages would be difficult, but one very interesting to Englishmen, because he was himself of their nationality and because he lived within the memory of their own times, was Thomas à Becket, the Archbishop of Canterbury, who was put to death by the minions of Henry II. when that monarch had expressed his displeasure with him, and who, conceived in the popular mind as suffering torment for his faith's sake and standing upon an ecclesiastical eminence, was not merely regarded as a martyr for the cause of the Church, but was canonized as a saint. Stories of his life, a mixture of authentic history and fiction, were long current, told over and again, and reduced to writing by some unknown priest or monk of the early part of the fourteenth century.

This fragment of about twenty-five hundred lines is especially interesting to the student of philology, as being written midway between the romances and chronicles of an earlier date and the new English of Chaucer.

Examined as the basis of grammatical investigation, this poem presents, as the most prominent fact to attract notice, a great difference from the language of the century previous to its composition. The introduction of French words alone is sufficient to change the whole appearance of the text from one of earlier date. Add to that the result of the constant tendency for shortening forms, the usual curtailing of the Anglo-Saxon and semi-Saxon endings, and we have the language as it exists in the early part of the fourteenth century. In the discussion of the language of this fragment, it has seemed best to

follow the ordinary methods of philological research, and to study the different parts of speech separately, and in the usual order.

As not all the composition was carefully investigated for paradigms, some of these remain uncompleted; but enough has been done, it is hoped, to show what was the general tendency of the language of this period, and what were the principal regular grammatical forms, and what were the chief exceptions to regularity.

NOUNS.

Nouns Masculine.

Sing.	N.	e	—	man (me).	Sing.	D.	e	— e	man.
	G.	es	es	manes, 2376.		A.	e	—	man.
Plu.	N.	es	es or is, 2418; but see 2468.				men		en.
	G.								
	D.	es	es				men		en.
	A.	es	es or s				men		en.

Plurals are found in *en* of all genders, as follows: —

1885 bellen. 1951 schrewen. 2251 emeten. 2373 honden (fem.).
248 (also 2419, 2421) schuldren. 2498 churchen.

More masculine nouns end in — than in *e*, but no definite rule can be formulated, so that we can know which form to expect. Some forms worth notice are these: —

1790 rede, seems to have *e* uniformly, though from Ags. rāed, cf. 2006.

1790 govern, from the French governe. 1807 and after, sire, voc.

1867 and 1971 freond (in voc. plu.). 1813 lymemele, a noun become an adverb, cf. modern English piecemeal. 1859 al dai used adverbially; fo, n. d. a., but fou, n. and dat. plu.

2797. A substantive adj. is found in the wise, cf. 2250.

2113. Another case, god used as a noun. See also 2409 (so in Anglo-Saxon).

2226 seems to be an older form than most of the text.

2285 fader in the gen. singular, without *s*, as survival of the Anglo-Saxon.

Nouns Feminine.

	Sing.		Plur.	
N.	e	moder.	N.	es.
G.	e, or —	moder [2286?], 2489.	G.	
D.	e	moder.	D.	es.
A.	e	moder.	A.	es.

Some of the noticeable feminine forms are as follows: —

In line 1819, par charité, French words, with a French construction.

1836 and 1872, threting, dat. and acc. without the *e*.

1866 mansing, dat. without *e*, but cf. 1901 and 1873, where the acc. has *e*.

1916 loking without *e*.

1882 and '83 croiz, here plural, but certainly singular in 2103. This word seems indeclinable, so far as distinction between nom. and oblique cases is concerned.

1887, stret is noticeable in the dat., as is also in 1979 boc.

2129 soul (here acc.), Ags. sawel, usually has a final *e*. See also 2335, 2424, and others.

2129 churche (gen. sing.). See also 2296. See also 2322, of ende day, and 2323, deth unel. The churche dore, 2307, seems very probably to be a compound word.

2263, wordle, in which a common transposition occurs, where *d* and *l* change places, as is frequent in this word.

NOUNS NEUTER.

SING.	*e*	—	PLU.	
N.	e	—	N.	es (or —).
G.		es.	G.	(ne 2007).
D.	e	— or e.	D.	es.
A.	e	—	A.	es (or —).

The neuter nouns ending in — are much more frequent than those ending in *e*, and very naturally. There have been noted a few interesting forms, which do not readily fall in with the paradigms. These are: —

1815, 2437, etc., *ζer*, the regular form of the noun in all cases except the gen. of both singular and plural. In the cases instanced, it seems to be acc. plu. of extent of time. 1835 schif in dat. keeps its *e*, which is not found in the nom. 2007 see childerne as a gen. plu., the only one found. 2144 schef preserves its old regular form in the plural, Ags. scéap. 2193 here is plural. 2187 and 2225 hors seems to be plural in these cases, as being numbers.

NOUN CONSTRUCTIONS TO BE NOTICED AS UNCOMMON.

1867 loverdes leve the King. 1876 amorwe, an adv. formed from a noun and prep., as also 1931 akneo (cf. 2370). 1924 pound (plu.). 1966 *that* folk where a preposition would be more natural; cf. *Pronouns*. 2004 mile (plu.) like hors; still heard colloquially. 2232 Seint Johnes the Baptist (cf. 1867). 2285 and 2286, fader and moder (gen.); cf. *Fem. Nouns*, and elsewhere.

Nouns Proper.

These nouns are instanced in the order in which they occur, and are useful in comparing the forms of the early fourteenth century with those of the present day.

Seint Thomas, Engelonde (also without *e*), France, Whitsonde, Rome, Everyk, Salesbure (also *y*), Londone, Jesu Crist, Canterbure (also *y*), Dovere, Sire Renald de Warenne, Sire Randolf de Brok (also Brok*e*), Gorveis, Sandwich, Thomas, Jesu Crist, Palmsonedai, Jerusalem, Pope, Cristes (gen.), Normandie, Sire Renald de Fizonis, Sire Hughe de Moreville, Sire Williem the Traci (also Williem Traci), Sire Richard the Brut, Sire Robert de Broke (also without *e*), King Henri, Fridai, Saltwode, Childerne-masse-dai-Tuesdai (also Tywesdai), Seinte Marie dai Magdalene, Seinte Marie, Seint Dionis (also Seinte), Edward Grim, Grantebrugge, Gywes, Godspel, Excestre, Seint Austines (gen.), Seint Johnes the Baptist (gen.), Argenteyme, Templers, Claundone, Scotlonde, Sire Geffrai, Britaigne, Kyng Richard, Kyng John, Sire Geffreies, Stevene, Honori, Pandulf, Water, Reyns, Sire Huberd de Brom, Norhamptone, Ponteney, Jesus.

Nouns from the French.

By the time of this composition French words were becoming common in our language, but they occurred in no such proportions as we find them in the English of to-day. The number seems very small for so late a period as this. In this list, proper nouns are not included, as they are mentioned elsewhere. The most patent French derived nouns are the following: —

1790 gouverne, 1793 onur, 1794 condut, 1795 honur, 1797 letres, 1798 sentence, 1801 digneti, 1819 charité, 1821 grace, 1838 croice, 1839 signe, baner, 1843 cri, 1846 joye, 1853 cas, 1856 semblant, 1861 pres, 1868 trespas, 1870 deserteisoun, custume, 1873 manere, 1875 respit, 1878 contrai, 1879 parosche, 1880 processioun, 1882 croiz, 1885 taperes (i. e. = tabors, which the sense seems to favor), soun, 1886 instrument, 1887 noyse, 1895 palefrai, 1899 paleys, 1903 frere, 1905 place, 1907 forme, 1908 surance, 1921 poer, 1923 cofre, 1937 despit, 1944 traitour, 1960 folie, 1961 messager, 1967 predicatiouns, 1985 clerk (also 2933 clerc), 1986 wardeyn seems to be old French (yet ward and warder are early English, from the French through the Teutonic, like *guerre*, etc.), 2014 chambre, 2016 clerkes, consail, 2018 message, 2020 comandment, 2023 baronye, cf. also 2028, 2024 chief, 2033 servage, 2048 croune, 2136 croun (= top of head), 2056 accord, 2072 fei, 2078 maners, 2085 armes (French, but armes in 2073 is English), 2087 cloistre, 2088 compli, 2093 merci, 2098 servise, 2099 castel, 2100 foles, folies, 2109 hure, 2110 mantel, vylté, 2126 oreisoun, 2128 avowes, 2137 face, 2141 Gywes, 2142 disciples, 2152 marbel (?), 2152 poynt, 2156 pavement, 2158 colour, 2159 diademe, 2161 peynt, 2185 tresorie, 2186 robberie, 2187

tresour, 2188 chartres, 2192 franchise, 2208 auter, 2230 solempneté, 2231 minstre, 2236 abyt, 2238 covele, stamyn, 2239 seculer, 2240 priveité, 2243 ese, 2248 creature, 2272 consail, 2273 angusse, 2275 pité, 2289 euchesoun, anny, 2292 penance, 2293 priveité, 2315 stat, 2318 miracle, 2333 patriarcs, 2334 virgines, 2340 court, manere, 2360 contek, 2376 tombe, 2391 ensample, 2395 meneisoun, 2399 heir, 2402 heritage, 2413 miseise, 2425 prisoun, 2428 fyne, 2431 sauter (this word, found in Anglo-Saxon, is Latin of the Second Period, not of the Third, but this form seems to be from the French), 2443 tricherie, 2450 legat, 2451 pardoun, 2455 priours, persones, 2456 barounes, 2457 serjants, squiers, 2462 presse, 2465 covent 2479 justise, 2483 Trinité, 2488 cheances, 2506 feste.

PRONOUNS.

Personal Pronouns.

Sing.	1st.	2d.	3d. M.	3d. F.	3d. N.
N.	y, ich	thu	he	her	hit
G.	mi, myn	thi, thin	his	hire	
D.	me	the	him		hit
A.	me	the	him		hit
Plu.					
N.	we	ȝe	hi (he 1872) (he 2191)		hi
G.	oure	ȝoure	here		
D.	ous	ȝou (ȝu 2105)	hem (him 1999)		hem
A.	ous	ȝou	hem		hem

The *y* and *ich* seem to be used indiscriminately, or at any rate the distinction is not a uniform one.

The dative and accusative are alike in the pronouns, showing that the distinction between them had already been broken down.

The gen. plural ends in *e* before vowels and consonants alike, but in the singular a well defined line is drawn; *mi* and *thi* are used only before consonants, while *min* and *thin* are used before vowels or the letter *h*.

The second person nom. singular in the interrogative form is *tou*, as *havestou?*

In writings of the same date as the one under discussion, we often find the tendency to a pronoun in the dative case as the apparent subject of the verb. Some instances in this work are as follows: —

1st person dative singular as subject, as, me thinketh, 1925, 2035, 2072, etc.
2d " " " " " as, the reweth (this may be acc.).
3d " " " " " as, him thoȝte, lines 1, 3, 2378, 2395, etc.
3d " " plural " " as, hem wende, 1911, 2466, etc.; hem agros, 2200.

No forms of the genitive singular of the third personal pronoun appear in this piece; the place of that form is often supplied, in the same way as in the English Bible, by the word ***thereof***, meaning simply *of it*, as used in lines 2213 and 2257.

The form *thereto* occurs several times in the sense of ***to it***.

Possessive Pronouns.

The possessive pronouns are merely the genitives of the personals, all the plurals ending in *e*, as does also the feminine of the third person singular. In the singular, the forms ***thi*** and ***mi*** are used before consonants, and ***thin*** and ***myn*** before vowels or ***h***. The third masculine is ***his***, indeclinable, as are the others. In form the vocative is like the nominative.

Intensive Pronouns.

The emphatic forms of the possessive occur in the same form as in modern English. We have in 1822 *myn owe* in the dat. sing., and in 2060 *thin owe*.

In this composition we very frequently find a simple personal pronoun in one of the oblique cases where the modern English would use an intensive. For example, *themselves* is often expressed by *hem*, as in 1802, 1955, 2189, 2195, etc.

In the singular, too, *him* dat. sing. must be translated *himself* in 1928, 2010, 2174.

The form in *silf*, however, does occur as the nom. singular *himsilf* in 2255; in *himsilve*, line 2316; the nom. sings. *thusilf* and *the silf* occur. In the nominative we also find *oure Louerd silf;* and in the neuter is *the selve thing*, line 2478.

Demonstrative.

The forms *this* and *that*, indeclinable in the singular, are found in all cases and genders of the singular. The plural *this* occurs in the nominative; *that* is not found in the plural, so its form can only be conjectured.

Relative Pronouns.

The relative pronoun of all genders is *that*, both in the singular and plural; the forms *who* and *which* do not occur in those forms. In one shape, however, we see the former; the dative both of the singular and plural has the form *wham*, as dat. sing. *of wham*, 2462, dat. plu. *of wham*, 2001.

The pronoun *ho* does occur as a relative once, but not with the ordinary relative meaning; it is in line 2222, where it means *whoso.* The relative pronoun *that* is used in 1849, where modern English would use an adjective. So too several times we find this evidence of a careless use.

Compound Relative.

The compound relative, meaning the words that we should express in modern English by *what* or *that which*, is *that*, the same form as the simple relative; it is used in all cases of the singular, and in the nominative plural; *that* is also used in line 2240, equivalent to *those who.*

Interrogative.

The interrogative pronoun occurs only in the nominative singular. It is *ho*, the antitype of our modern *who* as interrogative and relative.

Indefinite and Occasional.

Under this heading I have grouped all those pronominal forms which do not readily resolve themselves into some one of the other classes.

me or *men*, as used like the French *on*, as the subject of a verb referring to an indefinite subject. This is very common, and in line 2486 we have *me* as a neuter nominative.

Other, meaning "another," is found in the nom. and acc. sing. and plu. The dat. plural is *othere*, which form is also used as nom. plural. *Thother* is used both sing. and plu., as 1996 sing., 1835 plu. *Thothere* is also found in nom. sing. 2151.

meni on = "many a one," nom. as 1809, 1840, 2454.

non = none (nom. sing.), *one* = "alone."

echon in all cases of singular, but *echon* dat. in 2421, and nom. in 2429 and 2474.

enes is acc. sing. neuter.

nothing is found in nom., dat., and acc. singular.

alle in dat., nom., and acc. plural masculine.

summe (nom. plu. masc.).

pece and *other* = "piece by piece" (nom. sing. 2420).

bothe (nom.), *beire* (gen.).

ADJECTIVES.

The vocabulary of this author is very limited in regard to adjectives. The adjectives are many in number, and almost every noun has its accompanying epithet; but while in number they are so many, in

kind they are very few; almost every object or person mentioned is either good or bad, "holi" or "lither." The paradigms are in no case complete in this fragment.

Strong Declension.

Sing.	*Masc.*	*Fem.*	*Neut.*
N.	— 1939, 1940, 2021.	— 1789, 1998.	
G.		No genitives are found.	
D.		*e* 2083, 2089, 2087, 2166, or — 1826, 1974, 2099.	
A.	— 2034, 2444.	— 1937, 1980, 2033.	— 1988.
Plu.			
N.		*e* 2001, 2480, or — 2066 and elsewhere.	
G.		No gen. plu. is found.	
D.		*e* 2466.	
A.		— 1920 (?).	

The plural is alike for all genders.

Weak Declension.

Sing.	*Masc.*	*Fem.*	*Neut.*
N.	*e* 1848, 2086, or — 1897, 2097	Lacking.	
G.	2069 (holi) 2376.		
D.		(owe) 2062, 2429.	*e* 1894, or — 2483.
A.	*e* 1801, or — 1804, 1833.	*e* 1872, 2406.	*e* — 2445.

Plu. Same for all genders.

N. *e* 1865, 2031, 2250.

G. Lacking.

D. — *e* 1791.

A. *e* 1802, 2193, also (privei, 2188).

Comparatives.

2011 leng, vylloker (adv.), rather (adv.), ere (adv.), rather 2051 (adv.).
prestere 2106, heȝere, worse, next.
(moche-more) denoting intensity, 2034; denoting number *mo*, 2068, 2085, forthere.

Superlatives.

meste (the meste schrewen).

Numeral Adjectives.

O, on, 2253, enes (adv.); tuo 2277, tuei 2193, tueye 1914; threo, 1802, 1929; four 2001, foure 2405; vyf, 2068; six, 1850; sove, 2503; threttene, thridde, 1847, 2430; furthe, 2446; vyfte, 2178; sovethe, 1849.

ARTICLES.

The definite article is *the* for all genders and cases. The indefinite article is *a*, *an*, and *ane*.

ADVERBS.

Adverbs are formed from adjectives by adding *-e* or *-liche* (Ags. *lice*, modern English *-ly*). The former are the more frequent; as, sore, occurring 1787 and often elsewhere; faste, 1827, and frequently; wide, 1843; foule, 2070; softe, 2183.

Of the adverbs in *-liche*, a few are as follows: —

1897 myldeliche	1950 stilliche	1990 noleliche
2092 baldeliche	2205 duffulliche	

VERBS, WEAK AND STRONG.

Personal Endings.

STRONG.

Indicative.	*Present.*	*Subjunctive.*	*Imperative.*
SING. 1. — e	SING. 1.		SING.
2. — est, or st	2.		2. — —
3. — eth, th, — (2161)	3. — e		
PLU. — eth	PLU. — e		PLU. — eth

Indic.	*Past Subj.*	*Past Participle.*
SING. 1.	SING. 1.	
2. — e	2.	i —
3. — —	3. — e	
PLU. — e (1836), — en, i — e 2068 (2d pers. pron. omitted).	PLU. — e	

WEAK.

Indicative.	*Present.*	*Subj.*	*Imper.*	*Infin.*
SING. 1. — —	SING. 1.	SING. 2. —		— e
2. — est	2. — e, — i, —		— e	— i
3. — eth	3. — e	PLU. 3.	(assoili)	
PLU. — eth	PLU. — e		— i (granti)	(passi)

	Past.	*Past Participle.*
SING. 1.		
2.		
3. te, ^{k}ede (1793).		i — ed
PLU. — ^{k}eden (1803).		y — ed
— ^{n}ede (1804).		

STRONG. — PRINCIPAL PARTS ARRANGED IN ALPHABETICAL ORDER.

Present.	*Past Sing.*	*Past Plu.*	*Past Part.*
abide (abyd, imper.)		abide	
afonge (fongen, inf.)			
agros			
aloute			
atake (bitake)	aftoc, bitoc (toke) 1832		
bede (inf.) (biddeth = beten	(bidde = bitten	bad (both meanings).	bede, beden, bitten
bere		bere	ibore
			ibounde
	bigan	gonne	
	bicom		
	biȝat (forȝet, underȝet)		
breken	brak	breke	
	cast(e)	caste	
clipeth			
		chose	
		crope	
comest	bicom	come (perhaps subjunctive) 1817, 1830, 1833.	icome
do, don, done	dude (1837)	duden	ido
drawe (drauȝ imper.)	drouȝ	drowe	to-drawe
			idryve
	et	ete	
falleth	bifal	falle	
fleo		flowe	
forgyve	ȝaf		
forȝet	forȝet, underȝet		forȝute
forsake	forsoc	forsoke	
fynde		fonde, funde	founde, fonden
geve (geveth, imper.)	ȝof		
go	ȝeode	ȝeoden	gon, agone (2332)
hongen			
holden (hold, imper.)	huld, huld(e)	bihulde	
helpe			
hoteth (1st plu.)	bihet		
lie (= lügen)			
ligge (inf.), lith	lay or lai	leye	
nyme (binyme)	nom	nome	binome, ynome
	let	forlete, lete	
	quath		

Present.	*Past Sing.*	*Past Plu.*	*Past Part.*
rede		radden	
ride	rod		
seoth	say (1966)		
iseo	iseȝ, iseye		isene
sitte	sat		
singeth, singe	song	songe	
schryve			ischryve
		slepe	
smiteth, smyte	smot	smyte, smyten, smite	ismyte
spekt		bispeke	
	stonk		
swerie (inf.), swere (subj.)		swor(e)	
totere			
sle(e) 1803, sle	sloȝ	slowe	aslawe
		schove	
stent (3d sing.)	under-	stode	stonde
stonde (inf.), stonde (pl.)	a-		
			iwasche
	therste	therste	
uncover			
	wep		
		wode	
		woke	
			irite
1 worde, 2 worst, 3 plu. worþ(e), 3 worth (2034), as passive auxiliary.			
		ȝulde	

IRREGULAR WEAK VERBS. — PRINCIPAL PARTS.

Infin. Pres.	*Past.*	*Past Part.*
wende	wende	
	sende	
	ihurde	
telle	tolde, pl. tolden	
kepe	kipte	
		icouth
bringe	broȝte	ibroȝt
	roȝte	
lede	ladde	
Pencan	poȝte	
owe	auȝtest (2d sing.)	
1 sigge (sai, imper.)	seyde, seide, sigge (subj.)	
2 saiest (sai, imper.)	sede 2070	

ANOMALOUS, PRETERITE, PRESENT, ETC.

Wesan.

Indic.	*Present Subj.*	*Infin.*
SING. 1. am	SING. 1. beo	beo
2. ert	2.	
3. is	3.	
PLU. beoth	PLU.	

SING. 1. *Indic.*	*Past Subj.*	*Past Part.*
2. were (2066)	SING. 2. were 1862	beo
3. was, nas	3. were	ibeo
PLU. were, weren	PLU. were	

Habban.

Indic. Pres.	*Pres. Subj.*	*Imper.*
SING. 1. have	SING. 1.	PLU. habbe
2. havest, hast	2.	
3. nath, hath, habbeth (2044)	3. habbe	*Past Part.*
PLU. habbeth		habbe
PAST SING. 3. hadde	PLU. hadde	

Magan.

Indic.	*Pres.*	*Subj.*
SING. 1. may, mai	PAST SING. 1.	
2. miȝt (?)	2. miȝte	PAST SING. 3. miȝte
3. mai	3. miȝte	
PLU. mowe	PLU. miȝte	

Witan.

Indic. Pres.	*Subj.*	*Ind. Past.*
SING. 1. wot		SING. 1.
2. wost		2.
3.		3. nuste, wiste
PLU. wite		PLU. wiste

Don.

Indic. Pres.	*Past.*	*Subj. Pres.*
SING. 1. do	SING. 1.	SING. 1.
2.	2.	2. do
3.	3. dude	3.
PLU. doth	PLU. duden, dude	

Motan.

Mote is the only form that occurs, and it is found in first and third persons of the present subjunctive.

Must.

Moste is the only form; occurring in the plural of the past subjunctive.

Willan.

Indic.	*Present.*	*Subj.*
Sing. 1.	nele, wole, neli	
2.	nelt, wilnest (2047 from wilnian)	
3.	wole	
Plu.	wolleth	

Indic.	*Past.*	*Subj.*
Sing. 1.		Sing. 1.
2.	woldest	2.
3.	wolde	3. nolde
Plu.	wolde, nolde	Plu. wolde

Shall.

Indic.	*Present.*	*Subj.*
Sing. 1.	schal	
2.	schalt	
3.	schal	
Plu. 1–3.	{ schulleth / schulle } schullen	

Past Subj.

Sing. 1.

2.

3. scholde, schulde

Note. — Attention is called to the fact that the Greek letter Zeta is substituted for the Old English letter, which corresponds to *s*, *y*, and *g*, at different times.